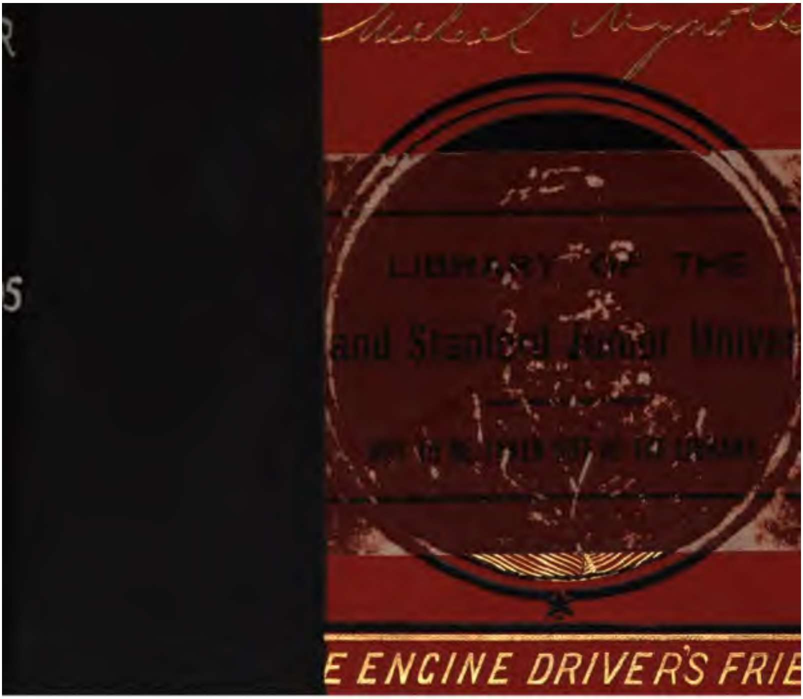
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PERSONAL OPINIONS

ON REYNOLDS'S "LOCOMOTIVE-ENGINE DRIVING."

From THE RIGHT HON. EARL GROSVENOR.

"It is most useful to railway men, and ought to be in the hands of all engine-drivers."

From SAMUEL W. JOHNSON, ESQ., *Locomotive Superintendent*, MIDLAND RAILWAY.

"It is eminently practical, and will be of great assistance to all who are aspiring to become first-class drivers, and who have the welfare of the company they serve at heart."

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From A. M. WATKIN, ESQ., M.P.

"I know no other book so useful for young men who wish to rise on the footplate."

LONDON

CROSBY LOCKWOOD AND CO.

7, STATIONERS' HALL COURT, LUDGATE HILL

George Stephenson

THE MODEL LOCOMOTIVE ENGINEER, FIREMAN, AND ENGINE-BOY:

COMPRISING

A HISTORICAL NOTICE OF THE PIONEER LOCOMOTIVE ENGINES AND THEIR INVENTORS

WITH A PROJECT FOR THE ESTABLISHMENT OF

CERTIFICATES OF QUALIFICATION IN THE RUNNING SERVICE OF RAILWAYS

BY

MICHAEL REYNOLDS

MEMBER OF THE SOCIETY OF ENGINEERS,
FORMERLY LOCOMOTIVE INSPECTOR, LONDON, BRIGHTON, AND SOUTH COAST RAILWAY,
AUTHOR OF "LOCOMOTIVE-ENGINE DRIVING"

LONDON
CROSBY LOCKWOOD AND CO.
7, STATIONERS' HALL COURT, LUDGATE HILL
1879

George Stephenson.

THE FATHER OF RAILWAYS

London, Crosby Lockwood, & Co. 7, Stationers Hall Court.

TO

DANIEL KINNEAR CLARK, Esq., C.E.,

AUTHOR OF "RAILWAY MACHINERY," ETC., ETC.

THIS WORK

IS

Dedicated,

AS A TRIBUTE OF RESPECT AND ESTEEM,

BY

THE AUTHOR.

PREFACE.

A GREAT philosopher has said that three things are essential to perform anything well: namely, Models, Rules, and Practice.

In view of the granting of certificates to locomotive engineers, firemen, and engine-boys, I have endeavoured to place before them *models* of self-help and self-reliance; *rules* that have proved themselves correct a thousand times over; and *practice* of the best possible railway service.

In supplying a model of perseverance, I was anxious to supply a real model, not a fabrication; and in all things, at all times, and for ever, a pattern such as all could wish for. I have met with many difficulties in my way. I have felt that what might suit a driver would not suit an engine-boy, and *vice versâ*. But certificates are intended to form character, by cultivating whatever is true, brave, and honest. Now, I came to the conclusion that the engine-boy knew nothing of the early struggles of the locomotive, and of what had been done *for* him; and that the firemen knew but a little more, and many drivers very imperfectly. It therefore occurred to me that I should be affording the engine-boy information, the fireman gratification, and the engineer models of perseverance, by noticing what Murdoch, Trevethick, Hedley, and Stephenson had done to establish the locomotive:—first as a road-engine, then as a goods-engine,

and lastly as a passenger-engine. The accomplishment of these results, giving us a speed of sixty miles an hour, and every suburban comfort against the anxiety of the city, demanded characters of the highest standard, and such as could be regarded with pride.

The men who gave us our railways could not boast of a long roll of ancestors; they were working men in every sense of the words, and on this account they were reasonable models. Again, they were, in feeling and opinion, aiming in their lives at something better than had ever been done before, and straining both heart and brain to accomplish it; and in this respect they were like ourselves, endeavouring to overcome every-day difficulties, and obtain some encouragement to make good any deficiency of which we may be conscious. A fellow-feeling makes the world kin, and by looking into the scenes surrounding the progress of the locomotive, in which Murdoch, Trevethick, Hedley, and Stephenson took part, there may be read page after page of gracious moments and dire despair. The struggle went on single-handed; signs of improvement everywhere were very faint, until at last, by the victory achieved at Rainhill, in October, 1829, Stephenson settled the question of the locomotive for ever. I hope the account of their life-struggles, of which I could only mention a few, will prove of encouragement to many; and as they belonged to the class of railway men, so railway men at the present day will find much to remind them of their own experience.

The strong mind of George Stephenson is pourtrayed in the likeness of him which forms the frontispiece of this work. Not many engineers can hope to rival in their lives the successful career of the man; but, at the least, his example may be followed, at whatever distance.

The *rules* laid down, for the first time, in these pages for the guidance of engine-boys, firemen, and engineers, have been carefully considered in order to insure success.

There is in every step a corresponding inducement to them to aspire by progressive experience and class-examination. Nothing has been left to chance. Step by step, with rank to encourage. I have not only shown how a man's nature may be cultivated, but how it may be trained for the benefit not only of the man himself, but also for the railway company and the public. As now constituted, the service is unpopular.* Hundreds of men go into the steam-sheds in a year, who in a few weeks go away disgusted. The ground is perished for want of cultivation. Every possible effort, as far as engines are concerned, have been made to improve the service of our railway engineers; but the improvement we want—and must have—will be of no avail unless it commences *within* the men first, so that the leaven may leaven the whole lump. There is no reason on earth why each of these men should not be encouraged to exhibit more intellectual skill in describing the engine fully on paper before passing for a driver;—if he cannot write, don't pass him. Then he might go on a stage further, and give a description of the working of his engine and of the traffic; he might go a step higher and grapple with higher questions touching the laws that govern combustion and the action of the steam in the cylinder, and prove himself fit for a better position.

It is proposed to grant him a certificate at each of these stages. First stage, third-class engineer; second stage, second-class engineer; third stage, first-class engineer. And similar series of stages for certificates for firemen and engine-boys.

As it is very easy to find fault,—much easier than doing the work,—I have laboured much in this cause, and have, in order to still further clear the way, reduced all the classes into a practical form, having almost put the examination words into the mouths of the candidates. There will be found, in the pages of this book, a complete system for the use of locomotive superintendents to work to; and

a comprehensive system for the engineers of locomotive engines.

Finally—the plan is simple, but to the point; and it leaves no opening by which any man can reach the foot-plate without having set before him all his duties. This much having been accomplished, it remains for the railway companies to assist in establishing in this country what is so much needed:—

Locomotive engineer's certificates.

Locomotive fireman's certificates.

Locomotive engine-boy's certificates.

For each grade, corresponding uniforms should be provided. The standing of the service would be raised fifty per cent. in a short time.

MICHAEL REYNOLDS.

STANDEFORD, WOLVERHAMPTON,
June, 1879.

NOTE.

In revising the following pages on the elevation of the status of locomotive enginemen, firemen, and engine-boys, and on the initiation of a system of certificates of their qualifications, I have been strongly impressed by the evidence of the enthusiasm with which Mr. Reynolds has laboured at the good work; by the exhaustive manner in which he fathoms the difficulties of the problem; and by the very hopeful means by which he proposes to educate and to raise the efficiency of the excellent class of men who manipulate our locomotive power. In the prosecution of this self-imposed labour, the author might justly have been sustained by the assurance that there are few indeed, if there be any, who possess like him the needful qualifications for the work.

D. K. CLARK.

CONTENTS.

PART I.—THE PIONEER ENGINEERS.

PART II.—EARLY HISTORY OF THE LOCOMOTIVE.

APPENDIX.

LIST OF ILLUSTRATIONS.

THE MODEL LOCOMOTIVE ENGINEER, FIREMAN, AND ENGINE-BOY.

PART I.

THE PIONEER ENGINEERS.

CHAPTER I.

THE LOCOMOTIVE MEN.

"WHO are the greatest men of the present age?" said John Bright in the House of Commons. "Not your warriors, not your statesmen: they are your engineers."

If we regard the achievements of Smeaton, Rennie, Telford, and Stephenson, "souls that lived alone and dwelt apart," we shall find in the difficulties they had to encounter sufficient to excite our admiration. They fought the battle of life amidst unfavourable conditions; their life struggles are full of dramatic interest to all, for the stern realities and uncertainties of life were present in every phase of their history.

Disappointments under such circumstances had no healing; for who could help them in matters that had their origin in their creative brains alone?

There were none before them, none after them, who had such difficulties to encounter as those which awaited these men of might.

There were no mechanics' institutions, scarcely any mechanical publications; these men had scarcely any library, there were no classes in their times. Yet, look at their bridges, look at their harbours, roads, canals, and aqueducts. Look at their lighthouses, breakwaters, railways, and locomotive engines.

Did ever such men live before? No.

Our greatest orator is right: our greatest engineers are our greatest men: truer men and greater men than ever hurled their battalions across a battle-field.

One may read between the lines the traces of anguish, faintings of heart, marks of the scorching tear, amid their labours. With no obliquity of vision, with singleness of eye, and oneness of purpose, they applied themselves to questions of the highest importance—whether it was the building of a bridge, or of a locomotive. Confronted with questions involving every conceivable difficulty, they worked their way with the self-confidence of giants.

Notwithstanding thousands of discouraging circumstances, they bore aloft the banner with the strange device "Excelsior," working on thoroughly and in a manly spirit—rising slowly and surely to fame.

In the history of iron and engineering, many chapters are written bearing testimony to limitless endurance.

When, haply, an avalanche of defeat overtook the

results of their labours, it only warned them. It did not utterly cast them down nor destroy them. It reminded them they were human. It told them that, after all, suffering under unknown conditions, strength came by struggling, and that the immortal side of humanity exhibited itself in heroic valour.

In the "Lives of the Engineers" are recorded the achievements of a class of men who have conferred the highest and the most extensive benefits on their country. One of these was George Stephenson.

George Stephenson, the immortal. The most enduring character in the history of railways and locomotive engines.

His name is known and revered throughout the civilised world.

George Stephenson is the hero of the last half-century in connection with railways.

Just as the Italians are musicians, and the Germans metaphysicians—by birth—so Englishmen are engineers, and there is nothing more natural than that Englishmen should apply their faculties to the science of locomotion.

By the labours of Murdoch, Trevethick, Hedley, Blenkinsop, and—last and greatest—Stephenson, it may be averred that we have secured such a blessing as man never before dreamed of.

The locomotive engine was not the invention of any one individual, it was the outcome of the reflections, taste, observation, and experience of many minds. It was not turned out perfect, like Minerva from the head of Jupiter, but "growed," like Topsy.

The locomotive engine is the last gift of God to Great Britain.

The establishment of the locomotive makes a story in itself: the story of a great battle, with adverse circumstances, opened by Trevethick as captain, and victoriously ended by Stephenson, gained at Rainhill.

"It was a most decisive victory," said the Duke of Wellington to Her Majesty, Queen Victoria, when showing the latter over the plains of Waterloo. It was a most decisive victory also at Rainhill, when Stephenson exhibited to the same duke the triumph of the locomotive.

Never a Cossack of the Don was prouder of his strong black charger than was Stephenson of his iron steed "Rocket" after that battle. To him it was a most momentous day.

It was in its results, also, very important from a national point of view, for he so completely defeated the opponents of locomotion by steam that they no longer resisted its development. It was impossible to withstand it; a pace of twenty miles an hour with the bleeding body of poor Huskisson, was too much for the opposition, and it was vanquished.

One enemy, who said the "iron horse" would never stand the fiery test, looked back and saw the "Duke of Waterloo" and the "Duke of Rainhill" holding audience together. "The crown of laurels," he exclaimed, "has this day fallen from stage-coaches." And he was right.

As the excited leaders advanced into the crowd, louder and louder grew the noise, and men, women, and children shouted, "Bravo, Stephenson! bravo, Stephenson!"

But we have said that the battle was commenced by Captain Trevethick.

Writing to a friend, Sir Humphrey Davy said, after looking at the first engine of Trevethick's, "I shall soon hope to hear that the roads of England are the haunts of Captain Trevethick's dragons."

CHAPTER II.

THE STATIONARY-ENGINE MEN.

THE first quarter of the century promised well for steam-engines: they were becoming popular; and to be connected with steam practice was taken as complimentary to a man's intelligence. Any one who belonged, as a principal or as a subordinate, to the Soho factory, working under Messrs. Boulton and Watt, was sure to command much respect, and to excite a feeling of simple admiration.

Mr. Boulton was really a noble character; he spent about £78,000 without realising so much as the value of a sou. When a personal friend asked him what he did at Soho, "At Soho," replied he, "we sell what all the world wants, and that is power."

He was proud of the shop, proud of the steam-engine; and it was fortunate for England that he was proud of engineers.

Watt was an engineer hailing from Greenock, wondering how the world would "finish" him, and if he would have to go the way of most clever men, when providentially he was rescued by Boulton.

Boulton had some metal of intrinsic value in his pocket—gold; Watt had a head that could contrive and scheme. Boulton at once saddled himself with Watt, and

Watt turned out what Boulton took him to be,—a good engineer—and both men became exceedingly rich.

As pioneers of the progress of the steam-engine, these two men commend themselves to the gratitude of all those whose course in life lies in the line of stationary-engine work. They turned out a man acquainted with every mechanical turn in machinery; that man was Murdoch, the inventor of the first locomotive, of whom more hereafter. Murdoch handed his ideas over to his pupil, Trevethick, who did more towards making a locomotive a success than any one before him. When the engine was brought under Stephenson's notice—which spoilt him for an engine-wright—it was in its infancy. There were several men about the year 1815 who, notwithstanding the difficulties which lay thick around them, and which brought much anxiety and cost much money, should be always mentioned in an historical account of the "Monarch of Speed." This is all the more necessary to be stated here, because the subject is interesting to all who are interested by the locomotive; and there are very few people nowadays who are not, though they may know very little of its history. There were grave doubts for years as to whether the locomotive would ever answer. These we intend to investigate. The engine was making progress when Stephenson took it in hand. This we intend to investigate also. And, further, we shall endeavour to show, step by step, what each of the ingenious persons, whose names are inseparably associated with it, have done.

George Stephenson and the "Grand Allies," his masters, did much; *they* found it an infant, *he* made it a giant.

How is it possible to contemplate our great locomotive power without feeling that we should like to have some knowledge of the toiling, that is going on daily and nightly in the steam-sheds to keep the traffic going?

It is our intention to explain how all this is done, and what is necessary to ensure success. We shall also determine what improvements can be made with safety and comfort.

The system is not perfect by a long way. There is all reasonable security, but all the advantages are not seized, and the service is not developed into the high state of efficiency to which it might attain. We would have provision made for further advances, changes for the better—work of reformation going on in all parts of the locomotive department.

No doubt, the ceaseless strife that goes on to keep up with the times retards any action for setting aside present arrangements for others. There is striving in all directions in the working department. Strife for approval in meeting the demand for new engines as fast as others give out. Strife to shine in all undertakings; strife to control; strife for power; strife for wealth.

In the running-shed we shall find a combination of all the virtues and vices of mankind.

The lambs of the Lord and the devil's imps cleaning, firing, driving, and governing.

We find here men who cling most tenaciously to every species of old habits and customs, and to power.

We find here men forming a majority to successfully set aside any measure that is likely to interfere with private interests.

We find here men who, being in too great a hurry, strike before good sense and caution find place.

Statues raised to the progenitors of the steam-engine awaken surmises that there is something in steam.

There are statues to Watt and to Stephenson, and yet neither of them invented very much more than other great men; but they did what other great men did not, they took *steam* and tried to administer to the necessities of the hour, and each succeeded in his own sphere.

It is idle to sit down and say "I will invent," unless there is something to direct such a decision. Great men rise from obscure positions simply because they do the right thing at the right moment.

The effect is to lessen some source of apprehended evil and partially destroy it.

Every improvement, every novelty in science, or in art, is the fertile parent of new wants. Want gives birth to new supplies, and every advancing step taken in the endless field before us leads on to some fresh advantage. The man comes, and things hidden from view come with him.

Many discoveries and inventions have been made involving, indeed, a higher degree of intellectual power in the cognizance of matter, its laws and properties, as well as a more varied ingenuity, as regards construction and mode of application. The ship with her accessories, and the degree of knowledge required to conduct her through a distant and perilous voyage; the lens by which we are enabled to soar into the boundless regions of space or scrutinize the countless myriads of animated beings whose existence the unassisted vision had never else discovered, and many

other things, might be mentioned to show that the exhibition of high intelligence is not confined to the invention of the steam-engine.

But to trace the origin of the invention, although a very delightful task, and a matter of earnest inquiry, would be a long affair. It is right to render homage where it is due, and to clothe with honourable mention the names of those who by their illustrious acts really deserve it. Look at the effects now wrought by those great men who sleep the sleep that knows no waking.

The steam-engine traverses the rails and the seas in defiance of winds and tides; the earth gives up her metals and minerals, and we receive from the labours of our predecessors a goodly heritage. All the hard scheming was comparatively done years ago; knowledge now lies waiting to be gleaned; and time itself moves not so fast as improvements do.

CHAPTER III.

THE LOCOMOTIVE AND ITS DRIVER.

BLUCHER said when he first visited London, "My God, what a place to sack!" and if Denis Papin, Savery, Leopold, and a host of other engineers, Stephenson of course included, if they could make a visit to King's Cross, and see one of Patrick Stirling's magnificent "goers" and run a trip from London to Grantham, one hundred and five miles, with steam full on, they would say, "My God, Stirling, what an engine!"

It is a difficult matter to prophesy truly, but it may safely be said that we are not yet at the end of the improvements that have been going on of late years. There will be a change, and that in the direction of speed; perhaps there will not be much change in the engine; but in a short time, one hundred miles in the hour will be attained.

The ultimate achievement of the locomotive has yet to come; what has been done has been well done, and it is simply an act of justice to recognise that the locomotive superintendents of the present day are the best mechanics that have ever placed an engine on the metals. Look at their plans, their progress, the speed, the consumption, the endurance of their locomotives!

There is a marvellous show of crack steeds at this hour in our steam-sheds, such as man never saw before. They make life more than ever pleasant and endurable; they are the Alpha and the Omega of our aids to enjoyment; they work us into town from a pretty suburban villa, or they sweep the rail like a thing of life from the south to the land of brown heath and shaggy wood, land of the mountain and the flood, and back. This is a fortunate time for travellers, although not many years past the performance of a journey, especially a long journey, was a matter of great concern. The times are different. We can not only travel in safety, but we can travel with comfort—with every comfort,—in winter as well as in summer, by night and by day.

Not long ago, a happy wife residing in London, received a telegram from Edinburgh, informing her that, unless she started at once, she would not see her husband alive again. The "unhappy" wife rang for her servants. "Edinburgh at once," said she. In half an hour she was at King's Cross, and in nine hours and a half her carriage was speeding its way down Princes Street, in Edinburgh, the capital of Scotland.

Does a Thalberg or a Liszt make the piano sing under his fingers? Does a Paganini or an Ole Bull draw ravishing tones from the violin? Does the good right hand of Joachim pour imperishable sounds into the realms of your innermost soul, until the lips quiver, and the heart throbs, and you feel that they render palpable the thought that possesses them. Mark their laborious efforts to embody and express all that is within them. It is their existence, and, overflowing, it becomes a blessing to you.

So, on our great railway systems, the noble object is SPEED, and to maintain this, and at the same time to touch every heart, it is necessary to run as flame ; and all the natural powers of an engine-builder, to keep pace with the times, must be directed towards achieving a triumph. A higher speed is possible, that is a fact. The next best thing to keep up the character of our railways, to report progress, is to leave nothing neglected ; until it is impossible for an observer to suggest any improvement, so long as an individual can walk up to the engine and point out any deficiency, the result is not satisfactory.

With absolute sincerity of purpose, moving on until the voice of criticism is stopped: this is the way to arrive at the fullest state of proficiency.

The *feeling* of satisfaction is highly dangerous. The ground whereon we stand is never free from those who are on the march ; we must either go on or be left behind. It is quite certain that the improvement of locomotives, and locomotive questions, will not stop for any one.

An improvement may be open to attack, but it was never yet known to be utterly defeated. Mistaken judgments may raise doubts. Ingenuity may make points in opposition ; but daily life shows that, against real merit, language can produce no lasting effect. The truth will prevail. We might give an instance of this in the progress that continuous brakes are making at the present time. Take a glance back a few years, when a teacher on the merits of brakes, continuous in the hands of the driver, was deemed foolish. Gradually the tide is turning, and our drivers will soon have all the retarding power in their own hands. The sooner

the better. They ought to have it as early as possible; railway travelling would be rendered much safer.

It is well known in railway circles that hundreds of hair-breadth escapes have been made, and engine-men almost terror-stricken, by reason of their not having the brake-power entirely in their hands, so arranged that any unforeseen or accidental circumstance might be instantaneously met. Many engines are now fitted with brake-blocks on their driving-wheels, and the power to stop is highly appreciated by the drivers, who feel safer under such a system, and would not part with their own engine fitted with a brake for one not fitted. This is an improvement that does credit to the times. Of course we are living in a sharp age. "Onward" is the motto, and those who wish to keep up to the times require to press all good improvements into the service.

Still it is sometimes necessary to strain every nerve, cite and re-cite in the fullest manner the potent benefits to be derived from some change that would bring about many effective measures, exhibit a striking desire to fill in one more page of prudence, and infuse principles that shall acquire large influence with a moderate amount of sagacity and bring forth vigour and life. But on the railways, many a good thing goes begging for years before it is noticed. But one has only to wait. There is room at this hour for the introduction of a system that shall foster the life within, that dares noble objects, that aims high, and which shall enter into a crusade and cast down effete idols of pretended knowledge, and tear up by the root false notions.

The complete inability of the locomotive engineer to analyse the engine anatomically and physiologically, is a great deficiency. It is unfortunate that he cannot

explain the laws that govern combustion, and it is a national shame that the triumphs with which he charms the world, have never to this day been properly recognised.

We are writing in a land, in a country, where the locomotive was born, reared, and shaped, until it has become a magnificent mechanical achievement of the highest order. We know it, we see it every day, and rejoice in its progress; but between the engineer and the engine we have stirring and conflicting impressions. He is not so surpassingly magnificent, and at the sight of his cleading we shake our heads. Could he who designed and built the engine not have formed his engineer in a more elegant mould?

It is not to be doubted that the remarkable advance of the locomotive has led to the neglect of the man. The builders have had to scheme and struggle to meet the growing requirements of an accumulating increase of traffic.

For half a century this has been going on; for half a century, drivers have driven in all elements, and there have appeared no improvements in their status. Well, now the present question is, Shall there be marks of intellectual distinction for them? Signs of life? Yes; rivalry between Giles a ploughman and Giles an engineer, such as may do the heart good to witness. Signs of power? Yes; such as will repel the idea that nothing can be done, that the case is solely and absolutely useless. Signs of resolution? Yes; and strength enough to draw up all the sinews and charge home on old habits and thoughts.

Who says that our locomotive engineers and firemen are not keeping pace with the engine in its progress,

and need no helping hand? Whosoever thou art—M[illegible] inquietissime?—thou liest most unblushingly.

There is a touch of reality in that keen sarcasm which circulates in the steam-shed area. The dialogue, however, is good and is sufficiently illustrative.

"Driver, what is smoke?" said a passenger. "*Smoke*, to be sure," replied the engineer. What a pity he had no knowledge of King Carbon.

The story is not worth much, because it would be a great mistake to take it for granted that our railway engineers are all in such a chaotic state. There are such cases as that indicated above, we know; but we know also that there are amongst them "patines of bright gold." There are hundreds of drivers and firemen whose lives are truthful, just, generous, and good, who know nothing whatever of natural philosophy, simply because it has as yet never been demanded of them to know, or to give any indication of their range of thought.

The spell between hard work and the higher walks in the world's great arsenal was never broken except by a few of our engine-men.

Tests of intellectual strength are unknown, and there is no inducement to self-sacrifice and reading up, to compare one's capacity with that of another.

But should it be so, think you?

We ask nothing of the mind. All we seek is toil, bodily toil.

The likeness between what is and what has been demanded is so exact, that we expect nothing. Are we justified to look on this state of things—so low—and [illegible]ve it? No; we want to see the service raised, but

unless some better plan is adopted, it will remain as it is. And remain it must not. The cold and cheerless lot to book "on" duty and "off" duty, the chances of being killed and a little "siller" at the end of the week, are not sufficient. Let the men have light, more light, and the advance will remove many a grievance, push the mountains of stumbling-blocks into the sea, and leave the rough places plain.

No industry, unaccompanied with intellectual advancement, is permanent; but when connected, they are the crown and glory of life.

The human mind, like the human body, loves and delights in exercise, and its delight is written in the bright and joyous face. It is natural. Neglect of the body reaps its reward; why should not neglect of the mind? On the other hand, what is more pleasing to the mind and spirit than to meet with something *for the first time*, by search. The impression is ten times more enduring than if it came without any ability or power on our part, and is equivalent to a conquest that fosters further resolutions.

Without this vital power, life is a sham, and there is the same thing over and over again: so many miles a day, so many hundredweights of coal consumed—that makes the heart sick.

Now, if we analyze all the forms of locomotives, we shall find that this state of things does not prevail. All is moving towards a better state of things. Witness the marvellous rapidity of growth of the engine! it is the wonder of the age. Great workers in modern locomotive-designing strenuously endeavour to produce a special and a better type of engine; they give every indication that they are in earnest; pressing onward,

they change the design, they change the fittings of the engine from place to place. What for? In pursuit of better results, with the hope of attaining them some day.

They exchange opinions on this and that particular class of engine, for this and that particular work, and strain all things to practical issues. They stop not at designing even a better-working splasher; all things indicate and show there is an inseparable relation between present attempts and a desire to attain some likeness to that which is faultless.

Who is astonished at the handsome engines of the Midland and the Great Northern Railways? We should be astonished if they did not improve. And why? Because of the above? No; not that alone, but because the majestic impression, weight, and grandeur of high aim are seen with the naked eye.

Under no other conditions than the continued effort to reach the beautiful and the true, could we have reached this wonderful perfection that we see.

It is the same painstaking that the late Mr. Beyer bestowed upon everything he did. It is the self-same spirit that for years moved, ruled, and guided Greek sculptors.

There is no questioning that locomotive history in the last few years has page after page of bright and happy impressions. These models, which adorn our steam-sheds and grace the rails when attached to mails, are grand products of our most gifted draughtsmen, to whom we are much indebted, whose powers have been developed in the best locomotive shops in England.

Well, what of all this? Why, the feeling that restrains the locomotive superintendent from assuming

that he has attained absolute perfection is, in many instances, confined to the drawing office; and we would like him to aim with just as much spirit, outside, to work out a model driver and a model fireman.

The drawing office and the erecting shop possess a charm such as the siren's song had for the ears of Ulysses. Let us have designed patterns outside; models of engineers and firemen on the footplate, and models of foremen in the shed.

The shed is not a saloon, nor is the floor covered with cloth, but its atmosphere is inhabited by men who are doing real service to the State; and the more we know of them, the more worthy they appear to be of consideration.

We would have a driver taught by models, rules, and practice—the best of all teaching—and distinguished for his fulness of knowledge respecting the engine and the working of the traffic, about which there should be no doubt. He should know the history of the locomotive engine, so as to connect himself with those who have fought the battles for him. To many men in charge of engines, the beginning is enveloped in mystery, and they know nothing of those who have lived and died trying to the last to make it a success.

We propose to remedy this misfortune, and hope to show that the history of the locomotive is intensely interesting; after that to frame a course of training composed of manual and intellectual exercise, such as shall interest our railway engineers more and more, by knowledge and work combined, in their calling; and, finally, to show how desirable it is to reward successful drivers with certificates of merit.

PART II.

EARLY HISTORY OF THE LOCOMOTIVE.

CHAPTER I.

THE IMPOSSIBILITY OF THE LOCOMOTIVE.

IN the full glare of a locomotive furnace, it is said, if we watch long enough, we can observe every incident in railway life. Be that as it may, we know that the railway is a stage on which we may see crutches, wooden legs, artificial arms, steel hooks, glass eyes, caoutchouc jaws, silver craniums, platinum noses, and evidence of smashed ribs, in abundance.

We look with pleasure on the life of our railway engineers, and therefore it can only be a pleasure to recall the scenes of their lives—and some exciting scenes—before the engine was fairly matured and landed. Their progress was not like that of timed pedestrians; their lives were affected by many accidents; life's fairest hopes were blighted. The traditions, strange as fiction, are true.

We will follow the development of the locomotive from 1763 to 1830, to enable us to accomplish a task for the benefit of young engineers who see only in the

shed what has taken years to bring about. There is no question of the interest of the subject. The story of past years, when every incident in the progress of the locomotive was watched for and eagerly conned, is never old, and it never will be so long as the locomotive exists. The tale will be told with interest over and over again, amidst locomotive changes, but without a change.

Some of the incidents in connection with the rise and progress of the locomotive have yet to be treated with greater breadth and feeling than hitherto.

The railway system is becoming a colossal affair, and every event and incident in its history grows in interest as time moves on. Nothing like the locomotive for power, rendering us almost ubiquitous, ever was known; and whilst we live and move in its circuit, busied with other affairs, we forget it. Indifferent to its use and its influence, we jump into the train without reflecting that at one time men ran about everywhere saying, "It is impracticable," and contemptuously smacked the whip and drove away. "Locomotives? Never! not if you live a hundred years! Believe me, they are all humbug." Reform came sooner than was expected by many, brought about by a mere handful of men;—we may almost say by one man, but that would be unfair: though it was chiefly through one man that we are now blessed with swift and cheap travelling. It must not be imagined that one man could do all this for us. It was not so; several were necessary, but the *last* man who took the work of steam locomotion in hand was the *first* to become famous—immortal in fame.

It was impossible, with any amount of foresight, to

have foreseen the actual results. They must, therefore, have been the dealing of a Divine Providence—in respect to this *one* and last man, very clearly so.

In disposition and temperament he was likely to accomplish the last stage of the organic development of the locomotive. He possessed ability, with patience to wait; and consequently he "fainted" not, though surrounded by innumerable difficulties of a most embarrassing nature. His name was Stephenson, and his claim on our gratitude and appreciation will be clearly established when we have shown what others did and suffered in the cause before him. Of course he did not invent the locomotive. Nothing of the kind. But, when it was in its infancy, he lived by the side of the road on which the engine worked, and the question immediately before us is this: What did he do to receive all the honour he has if he did not invent it? When Stephenson first took the locomotive in hand, he did no more than other men, but how he came to do more is an interesting question of history.

> " A pebble in the streamlet
> Has turned the course of many a river,
> A dew-drop on the baby plant
> Has warped the giant oak for ever."

A small road-engine was made in France in 1763, by a native of Lorraine. He was favoured with the notice of the government, who made an engine on his system on a larger scale, for the transport of artillery. It was under the direction of the inventor, Cugnot, and worked well for a time; but a little incident occurred by which the fortune of the inventor was changed right about. Cugnot, no doubt feeling confident in his machine, one day omitted to take all the

necessary precautions for securing as successful a trial as it was possible to make, and in rounding a corner he upset the engine; and poor Cugnot became a ruined man. After that accident, the French people locked up the engine, and left Cugnot to go a-begging. Genius! thy children, how seldom seen apart from want! The inventor of this engine was reduced to poverty; though afterwards he received a small pension from the government. But the pension was stopped by the Revolution, and a humane lady of Brussels (can any one give her name?) relieved him until Napoleon I. granted him a pension larger than the one he had lost, though only amounting to £42 a year.

Cugnot's machine is preserved in the Conservatoire des Arts et Métiers in Paris. It has a small copper boiler, with a furnace inside, and fitted with two small chimneys; two small cylinders and two connecting-rods acting alternately upon a single driving-wheel. The combination is capital: some time after, we adopted the two cylinders, and here, in 1763, was done what Stephenson patented in 1815, namely, to connect the coupling-rod to a pin in the spoke of the wheel. Taking it altogether, it was an ingenious machine. In fact, if it had not been ingenious, Cugnot would have existed without government aid. It is a very remarkable thing, that the inventors of duffing articles very frequently make fortunes before the inventor of a really good thing gets a copper.

It is to be hoped that the French people will remember poor Cugnot and in some suitable way recognise his undoubted abilities. But, there! what is the use of acknowledging a man's abilities when he is dead? Fancy the most that could be done now—what of it!

The next engineer who tried to make a steam-locomotive was the inventor of the excentric-motion, and the long D slide-valve, namely, Murdoch, the able assistant of James Watt, at Soho, Birmingham. Murdoch was in Cornwall when he made a model of an engine to run on the road. After he had completed the model, and was satisfied it would work properly, he looked out for a suitable place to test its performance. He was a very shrewd man and did things in the dark; and that does not always turn out well. But he would not rashly let every one know his scheme; and on this account he chose the closing hours of the evening for testing it. Should he fail, of course no one but himself need know of the failure; if he succeeded he could make everybody know of his success the next night. According to the state of civilization at Redruth at that time, stories of ghosts and kidnappers were credited. Old people of the place believed in the former, and not in the latter; and the young people believed in the latter and not in the former.

However, Murdoch made up his mind to try his engine on a piece of straight road near the churchyard. In this walk he set down a model of his locomotive. It looked like a child's toy; but it was a great idea, and a great invention.

The scene near the churchyard on that dark night when Murdoch was about to introduce a locomotive to Englishmen, was a memorable one, worthy of the artist's powers. It was not only dark, but still; the young folks of the village were asleep, and the old people were enjoying their firesides and pipes; as for the parson, he was in his study.

The hour had come, and the man, Murdoch, took from under his coat a tinder-box and flint; he struck the steel and kindled a fire under the engine.

In a few seconds the small spirit-lamp was burning, steam was got up, and the trial was found satisfactory. In another minute Murdoch tried it again, and the event of the evening took place. There, in the long gravel walk, the engine steamed up and down, puffing away and lighting up the sides of the road by its fire; cast on each side of the road was its own image. In the midst of Murdoch's glee and happiness, the worthy pastor left his study, contemplating going as far as the town. He entered the long walk where the engine was running. He was a worthy minister, in simple civil costume, stepping lightly, cheerfully, and confidently, for by God's grace he was no coward.

In virtue of his sacred office, he could not for one moment entertain the absurd idea that prevailed in the heads of the villagers: the idea of a ghost. He had all his life repelled such an idea, and believed in no man's story. "Seeing's believing," and what he saw he had faith enough to believe in. He entered the long walk, and although prepared to die, he offered gold, and blood even, if he could but be restored to the bosom of his family, for he had encountered the devil, who was loitering near the churchyard. The vicar had no revolver to cock, and therefore had recourse to gestures when Murdoch with a lantern faced him. It is not, said Murdoch, the evil one in *propriâ personâ*, but the *first* locomotive.

It is a most interesting picture.

Whether or not the minister persuaded Murdoch to "drop" his locomotive tricks cannot be known, but

one thing is quite certain: he made no more experiments nor did he embody his ideas in locomotive improvements afterwards. He remained with the Soho firm, and did uncommonly well as an inventor of engine gear.

The next man to become a locomotist was Richard Trevethick, an apprentice of Murdoch; it is very likely that the scene at the church put an end to Murdoch's views respecting locomotives, and it was not long afterwards that Trevethick dropped it too; though it answered better in his hands than in his master's.

CHAPTER II.

THE COAL TRAMWAYS.

BUT before we enter into Captain Trevethick's troubles we must, to make our history complete, make a statement, not a very long one, but one that will greatly interest young beginners; and that is—railways, or tracks of rails called tramways, were in use more than a hundred years before the locomotive ran on them. The trucks were drawn by horses all that time before any one thought of working them by steam.

Having made that statement, we can make another of equal importance, and that is, it was Richard Trevethick who first made an engine to run on rails.

This was at Pen-y-darran Iron Works, in South Wales.

About the year 1670, railways were made at Newcastle-upon-Tyne for transporting coals from the coal pits to the shipping on the river Tyne.

About this time, coal became popular for household consumption in lieu of wood, in the metropolis, and of course the demands for coal gradually increased on the colliery owners. They became impatient at the slow delivery of the orders, which were carted to the Tyne from the coal-pits. Necessity became the mother of invention. After some consideration, wooden rails were

laid down. It was a grand idea, and the man who first conceived it should have been immortalized. These rails consisted of straight pieces of timber laid down and embedded in the road. The feat is simple enough; but the invention was one of the highest order. Go to; invent and make thy fortune, build mansions, ride in a carriage, dine with great men. It is all very simple. Now if, after thirty-six hours' hard thinking, you have not found out how to do a simple thing with perfect ease, give inventors their due, and think how great a man the inventor of wooden rails must have been. Give inventors the laurels they earn.

These wooden rails were laid on wooden sleepers; and when they made signs on the surface of wearing out, small scantlings were laid over the holes or dilapidated portions.

They were, in plainer words, patched like an old shoe. This patching was a marked improvement, so much so that patches were applied where they were not needed; and finally, a road was laid consisting of two wooden rails one upon the other; the under rail was of oak and the upper one of fir wood.

This was called a "double road," and would not be so understood nowadays. These double roads, as they were called, had many advantages.

The upper or top rail, after it was worn out, or split, or broken, could be renewed without destroying or materially disturbing the under line proper. It made, besides, a much stronger road, and consumed less timber and less money to keep it in order.

The sleepers, at first, were exposed, and the horses knocked them to pieces with their feet; until a sharp man threw out a suggestion that they would be better

if covered up with ballast, and thus saved them from unnecessary waste.

At the same time, the waggons were in keeping with the times, but collisions appear to be like Shakspeare's plays, for all time. A smash now and then occurred, that made the hills rattle again, waggons were piled up in the air, and the coal was scattered in every direction. Sometimes, the waggoner or waggoners were found under the débris by screaming women. It was not all happiness then on the railways. What is the price of a glass eye or a wooden leg compared to the loss of a member? A mutilated body for some men, if it be only an eye or a leg, has broken the heart.

The colliery companies in many instances were to blame in not having sufficient available brake-power and men.

The undulating surface of the country over which these lines passed, was followed in their construction, excepting in the case of very steep ascents. Where any declivity or incline more than commonly steep occurred, it was made a "run" of.

Down these banks the pitch-in would happen. The waggoners stuck to their brakes like men; rude forms of brakes, which sometimes failed by being out of order, and many times by the rails being wet; and notwithstanding all the dexterity of the waggoners, the trips sometimes ended badly for the waggons.

These were the good old days when there were no cast-iron rails to be broken and replaced.

It has happened, in those days, that waggons have been left on the incline, scotched with a lump of hard clay, when the clay gave way, and the waggons commenced to run. The waggoner has been dozing by the

fire, with his ears closed, until the "mother" shouted out, "Jim, the waggons are loose." Jim in a trice has got out with the ropes across the road: but Jim's ropes were of no use; the waggons had a "way," very much as waggons have on an incline,—a nasty way. Jim's ropes snapped like threads, and in a crack Jim was up to his neck in muck. He had tried to stop the waggons, and he could not; so they must go into the end of the next waggon, or into the sea. Were these good old times?

These break-aways frequently ended in sad disasters, and keen investigations were made with the object of preventing them. The brake-power it was found was in fault; and, it may now be asked, when will this end?

Brake-power is the one thing needed; but we never have it in time; it comes too late, after the shock. At that time the knowledge of friction was imperfect; and no one thought of applying brake-blocks to wooden wheels; hence, the hind wheels of waggons were of cast-iron, to which the brake was applied; and the front wheels were made of wood, to which the blocks were not applied.

It is exceedingly interesting thus to trace the steps by which the improvements in railway rolling-stock have been achieved. Our ancestors feared to venture where we have found no danger at all; but, on the other hand, it is by doing what they were shy of attempting that we have attained to our superiority.

They had all the material,—wood, iron, copper, and steel. We have no more, but we have experience, and that is all in all: experience inures us to strife, accustoms us to command, and animates us to re-ve apparently immovable obstacles that impede

our course; yet, painful as the fact is, by the suffering, temporary and permanent, endured by the men whose industry and ingenuity have brought inestimable improvements to the front, and who have in many ways enlarged the sphere of labour by creating new work, by that suffering the men themselves have in many instances been ruined.

Experiments were made by the colliery owners with brake-blocks applied to all the wheels of the waggons. The results were favourable, and they brought about the reform that was urgently required. Brake-power! brake-power! It is a singular thing that scarcely any improvement is made at once. We perceive what is required, and yet we refuse to act until we hear a voice calling to us, "Put on the brake." It is so throughout society.

A man will persist in his ways; he is called back again and again; sometimes he has half-a-mind to act, his hand is on the brake-handle; but he hesitates; presently he finds he is going in the wrong direction more rapidly than ever. "Put on the brake," "Put on the brake." "What has happened?" cries the wayward one. "Put on the brake," "Put on the brake." The signal is at danger. "Where are you coming?" shouts the signalman. "Put on the brake," "Put on the brake."

The Railway Companies have been called upon to put on the brake by the friends of the killed, and by the sighs of the wounded. The public signal showed danger, and the directors saw it; but they had run by them so often that they were not answered. They noticed the danger, and drew up to it gently. But at last the chief signalman is heard, in earnest, calling

out, "Put on the brake," "Put on the brake." The warning was a reminder that danger-signals must be regarded.

It is the wisest thing in the world to apply a remedy at once for the complaint; it is reckless to postpone it even for a season.

Turning again to the narrative. After the brake-blocks were applied to all the wheels, there were fewer accidents; but it was felt that wooden rails were defective, the service they did was very limited compared with the cost of maintenance. Well, the matter attracted attention, as all defective systems should, and the result was the introduction of iron roads by Mr. Reynolds of Colebrooke-dale, Shropshire. The application of metallic surfaces to the wooden rails was, however, at first productive of much mischief and created much opposition. It is always thus with new prospects. The opposition in this instance was caused really by the want of more brake-power. It was not regarded from that point of view; but from one from which the opposition party could find their advantage. This is caused, said these people, by your rails having reduced the adhesive power, and the brakes are comparatively ineffective.

These savages, having made up their minds to oppose the introduction of an improvement, could not see that brake-efficiency was the next question. For, in the course of improvement, there is no going back. It had been found that iron rails were better than wooden ones; and that discovery was sufficient to settle the question. If the improvement elicited the deficiency of something else, then a remedy had to be sought in advance.

About the year 1770, the surplus force of gravity of the load descending one plane, was employed in dragging the empty waggons up the ascending plane.

This was a valuable means of saving horse-power; and it effected, besides, a great saving, in following the undulations of the country.

The idea belongs to the north of England, and was no doubt suggested by the action of the steam-engine winding minerals from the pits by means of ropes coiled round barrels.

The permanent-way had been improved, as well as the rolling-stock; tramways became paying concerns. Pace was quickened considerably by the introduction of iron for wooden rails, and there was on the whole a general impulse to advance. The rising popularity of the railways gave marks of progress visible all over the country.

Ingenious men ran to and fro; some to the Patent Office, and some to the Society of Arts, to ventilate their ideas, advance their projects.

Questions pertaining to railways took precedence of all others, and the atmosphere was full of railway talk, or rather tramway talk. Even a Committee of the House of Commons sat to report on tram-roads.

This was about the year 1776, before Stephenson was born, and when Watt was forty years old and had been in partnership with Boulton three years.

Inventions relating to railways poured into the patent offices: "A patent plate-rail;" "A patent brake;" "A patent wheel." One man patented a railway which was to be above ground supported on pillars—completely level—the pillars to be lengthened

or shortened, to suit the ground levels. It was not a bad idea, but it fell through.

But all matters connected with railways received their due share of attention at the time referred to. The result was, amongst other things coming to the fore, a stone sleeper instead of a wood sleeper.

The impetus given to the pig-iron trade, to rock-blasting and pick-axe work, was surprising.

"Come and dine with me," wrote a well-to-do squire to an ironmaster. "Can't," replied the puddler; "making rails for a railway—blast furnaces full go."

"Come and dine with me," wrote the squire to a colliery owner. "Can't," replied the collier; "making a new railway—immense demand for black diamonds."

"Come and dine with me," wrote the angry squire to a stone-mason. "Can't," replied he, "stone is in great demand—blasting from morning to night."

The squire embarks his capital in railway enterprise. The enthusiasm spread far and wide, amongst all classes—men of science, merchants, manufactories, even Tommy shops, all were stirred to their innermost fibres.

Cities, big and little, argued, discussed, disputed, or applauded the railway mania. It was talked of over sherry in private bars, and by boatmen in dingy taps.

The run on the Patent Office increased and the best thing out of many hundreds of proposed plans was a cast-iron plate-rail with an upright ledge, see Fig. 1, which was laid on stone sleepers. The plate was three feet long, the flange one-and-a-half inches high, and the sole or bed on which the wheels rolled three-and-a-half or four inches wide, and three-quarters of an inch thick. The stone blocks weighed about 120 lbs. each.

In the year 1801, the rail was much improved. There were so many defects about the above-noted plate-rail, that ingenious men set their minds to work to scheme something else.

Stones and dirt accumulated on the sole or bed of the plate-rail sufficient to throw the waggons off, and the sharp-raised edge was dangerous to the horses. Further, there was a great deal of frictional surface about the plate-rail; and, lastly, it was not a strong rail. Hence the invention of the edge-rail, Fig. 2. The real origin of this rail goes back to the days of the wooden rails, which were slightly rounded, and the flanges on the wheels projected downwards over the side of the rail to keep the waggons on the road; but this rail was abandoned for the plate-rail: the flangewas transferred from the wheel to the rail.

Fig. 1.—Cast-iron Plate-rail.

The plate-rail did not suit, and out came the edge-rail; a better form of rail altogether. The oval presented itself as the best plan to correct the faults of the plate-rail. The wheel for the edge-rail had a concave rim.

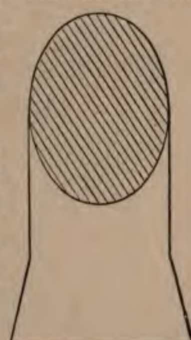


Fig. 2.—Cast-iron Edge-rail.

This was no visionary scheming, indeed, for it narrowly missed the accomplishment of a great discovery. It displays unquestionably great inventive talent.

At this time, 1801, much favour was shown for the

improvement of the internal communications of the country by using iron railroads. Every circumstance relating to them teems with interest, not only to the historian and the philosopher, but also to the mechanic.

Up to this time, 1802, there was no locomotive, but here we see a tolerably good road for it.

CHAPTER III.

RICHARD TREVETHICK.—THE FIRST WORKING LOCOMOTIVES.

WHO will be the first to introduce the engine? Answer Richard Trevethick,—The Great Trevethick,—Captain Trevethick. The philosophic poet Darwin was right when he undertook a prophet's mission :—

> "Soon shall thy arm, unconquered steam, afar,
> Drag the slow barge and drive the rapid car."

Murdoch, we must remember, gave up the locomotive, and his pupil Trevethick carried on the business.

In 1802, a patent was granted to Trevethick for a high-pressure steam-engine: the first high-pressure engine in the world. Its advantages lay in its simplicity, its cheapness of construction, its compactness, and the force that could be exerted by it, enormously greater than what had then been applied to any piston. It is stated that the pressure was even from seventy to eighty pounds per square inch.

But this sort of novelty frightened the people,—at least the bursting of the boiler did. Watt would not meddle with high-pressure steam, and was not he an authority? This nearly extinguished Trevethick.

He had forsaken now the well-beaten path which his contemporaries trod, and had done something that

others with all their fame either could not or would not do, and practical men looked askance at him.

But the engine was simple and beautiful. Connoisseurs jeered because, in the specification of the patent, he stated that it would either run a coach or drive a sugar-cane mill. But his bold deviation from the beaten track brought to him the experience of a good deal of trouble; but it brought with it also immortal fame. High-pressure steam and Trevethick are inseparable.

To pass lightly over this period, and indifferently by this machine, would be distasteful. There is a

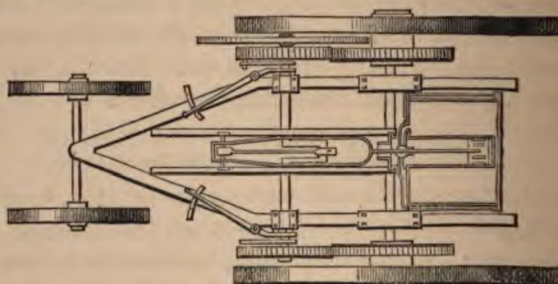


Fig. 3.—Trevethick and Vivian's Road Locomotive. Plan.

spell about that early era that makes it desirable to linger over the specification, and to examine the design of the engine.

What Boulton was to Watt, Vivian was to Trevethick, his cousin—the bank. The patent was taken out in the name of Trevethick and Vivian (Fig. 3).

The engine exhibits a deal of skill in combination never before seen. The extraordinary character of the motion is a treat in itself; being well adapted to produce the intended results.

If we examine it and compare it with the engines

constructed some years afterwards, we shall have cause to admire the superior genius whose mind shone in every part. The engine had one horizontal cylinder let into the boiler, which was in the rear of the hind wheels of the vehicle. The motion of the piston was transmitted to a counter-shaft, from which, through spur-wheels, the axle of the driving-wheels was worked round. The piston was forked immediately outside the piston-gland and carried forward, supported by slide-bars and a cross-head. The extension of the forked rod left room for the motion of the extremity of the crank to work between the forks. The position of the crank is very remarkable indeed, being fixed midway of the stroke, and working two spur-wheels at each end of the axle, that gave motion to two corresponding wheels fixed on the nave of the two driving-wheels of the carriage.

The wheels on the crank-axles could be thrown out of gear at any moment, together or separately, by levers.

A fly-wheel was employed to carry the engine over the centres. Now, this was a very simple and compact machine. The pumps were worked by springing levers, which were acted upon by a lever on the crank-axle. The regulator was worked in the same way.

At that time, cocks and valves were worked by various well-known methods, such as the plug, with pins or clamps striking on a lever. Sometimes they were worked by means of a ratchet, and by this means a cock was worn more uniformly and regularly than when its traverse amounted to only a half-turn.

Altogether, the work displayed much talent and ingenuity for arriving at a simple effect, namely, to give motion to wheels of carriages.

The external periphery of the wheels was smooth, but they were provided with "heads" that could be raised to "rough" them, and augment the adhesion, or hold upon the ground, in case of a heavy load, and when the driver wanted to "dig" into his work.

The engine was provided with spur-wheels to accelerate the speed, and the fire was urged by bellows worked by the motion.

We see that all this occurred in 1802:—horizontal cylinders, cylinder let into the boiler, and the motive power obtained through spur-wheels. It is essential that this should be noticed, because other inventors departed more or less from the plan. Even Trevethick himself did so; and yet at no period in the history of the locomotive engine have Trevethick's ideas been altogether put aside; there remain the use of high-pressure steam, and the employment of the horizontal cylinder and the crank-axle.

When his engine was finished, Trevethick astonished the natives—not the parson—about Cornwall; and, elated with success, he turned his eyes and his engine towards London. He shipped himself and the engine at Plymouth, and on the ground now occupied by the Euston Station, he "took the cloth off" and at once collected a crowd to view the Trevethick "dragon." He ran it for a few days, and in a carriage behind it carried many people; those who were fortunate enough to get a ride considered themselves lucky.

The excitement, however, was of short duration, for some one offended "Captain" Trevethick, and he took the engine away. It must have been trying, because he had brought the engine all the way from Cornwall to exhibit it. No doubt at that time it was rumoured

that the streets of London were paved with gold; but he found reason to think such was not the case. Many persons besides engineers and inventors have found that to be a false supposition.

Let that be as it may, there is no doubt that Trevethick, in London, picked up an idea quite new to him, which gave additional impetus to his extraordinary mind. But he appears to have kept it in reserve, as Murdoch did when he selected the dark hour of the night to try his locomotive at Redruth, and who can tell but the frightening of the worthy vicar in the dark turned the course of his intended exhibition of genius into an entirely different channel.

How often do we see the projects of clever men turned aside by simple circumstances.

At the time with which we are now interested, steam-carriages that could work on ordinary roads at moderate speed would have met with popular favour. Even George Stephenson's first engine did not travel faster than a horse could walk. But Trevethick was a man of high spirit.

Eminent mechanics and enterprising men will yet apply their minds and talents to road-locomotion, which has not yet received all the attention it deserves.

What could be better or pleasanter than a trip outside a locomotive carriage—a road "Pullman"—all the way if you choose, from London, say, to Wolverhampton, in the summer.

It is not impossible that the turnpike road, commonly called the King's Highway, will yet roll up its dust behind the "horse" that requires no rest, and the trip may be performed in four or five hours at the utmost.

Now the idea that Captain Trevethick picked up in London was this :—when he was in the metropolis, the Wandsworth and Croydon tramway was popular; much betting was going on as to what *one* horse would pull, and it was found by actual experiment to be surprising.

If Trevethick, instead of taking his engine suddenly away as he did, had arranged to back his engine against the horse, and made it his business to adapt his steam-carriage to the tram-road, it would have been a grand stroke of business, and he would have seized the opportunity of making a locomotive engine a "cockney" success. It is thought he had intentions, prior to his visit to London, of running his engine on the rails, but it is a fact that he did not, for some time afterwards, attempt such a thing.

He knew a great deal, no doubt, but there was one thing he did not know then, and that was, that a smooth wheel on an equally smooth *rail* would act with sufficient force to draw a weight behind it satisfactorily.

The general notion in the minds of most engineers was that, with smooth wheels and smooth rails, there would be no "go" in the engine. But, at the time to which we refer, no one had tested the notion, and when it was tested, it turned out to be purely imaginary.

The truth was wanting, and the result teaches us to test all things.

We next find Trevethick at Pen-y-darran, at some ironworks in South Wales, where he was erecting some blowing engines; and at this place, where there was a railway, he conceived the idea of placing an engine on it to work the waggons instead of horses.

The engine, Fig. 4, was made in a blacksmith's

shop, and, strange to relate, he put the motion on the top of the boiler, instead of keeping it down, as he had done in his steam-coach. He made also another departure from his original practice, by placing the cylinder vertically instead of horizontally, as he had done at first. Now his first attempt was a perfect engine, and it is impossible to understand what he thought of gaining by such radical alterations. If he had retained his old engine, taken off the body of the coach and remodelled the framing to suit a tramway,

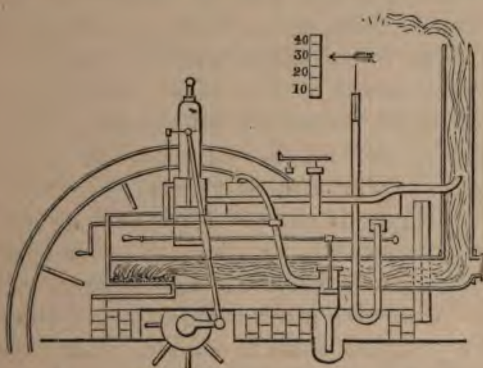


Fig. 4.—Trevethick's Railway Locomotive.

he would have had a very neat and compact locomotive.

But it was not to be so.

The minor arrangements of this, his second engine, have been variously described and illustrated by different authors, owing to the circumstance that Trevethick built several engines; and we may be positive that, with a mind like his, each would possess some essential improvement upon its predecessor.

Trevethick's *first* railroad engine had a cylindrical boiler set in brickwork; it had a syphon mercurial gauge, and a steel-yard safety-valve—articles that belonged exclusively to the stationary-engine trade.

The lower part of the cylinder was immersed in the boiler, and the exhaust was conveyed through a cistern to the chimney. By means of this excellent arrangement, great economy of fuel was effected; for much heat must inevitably have been drawn from the steam by the cold water that surrounded the exhaust-pipe. This is a very simple plan for saving fuel, and yet, in this country even, where coals are so expensive, the waste steam is lost, notwithstanding the thousands of units of heat which it contains. It is a curious fact that, although Trevethick put the exhaust-pipe in the chimney, its well-known effect does not appear to have been perceived by him, for he used fanners for urging the fire. There is the possibility that, owing to these fanners being worked by the crank or the piston, when the engine was moving, the fanners would receive all the credit, whereas much of the increased production of steam was no doubt due to the blast from the exhaust-pipe. Moreover, Trevethick, with the blast-pipe in the chimney, could not have reaped much benefit, unless the end of the pipe had been turned directly upwards, in the centre of the chimney. And, again, the chimney having been of such a large section, it must have required "something" to exhaust it. The upper end of the piston-rod was furnished with a cross-bar, or cross-head, placed in a direction at right-angles to the boiler, and also to the piston-rod. The cross-head worked upon two perpendicular rods, fixed to the sides of the boiler and parallel to each other. To the ends

of the cross-bar, or more properly the cross-head, the connecting-rods were attached, one on each side of the engine, with their ends coupled to cranks on the axle to which they were fixed. This axle was beneath the boiler and right under the cylinder, with a fly-wheel on it. The engine worked pretty well, but there was no sympathy for it, and there were few people who would not have rejoiced at its failure, for a number of persons were interested in the traction of the waggons by horses, and the sympathy of the mining population was not in favour of machinery. Many persons, who should have known better, had wagers pending that the engine would never answer.

The animus was real and stern. The engine broke tram-plates and hooks; at last it broke a great many, and finally it ran off the metals into a ditch. "Abandon!" "Abandon!" was the cry. And poor Trevethick, heart-broken, gave up all thoughts of the locomotive, and turned his feet towards Cornwall, where, for a time, he found it was more profitable to empty drowned-out pits. Many years after, when Robert Stephenson was residing in Columbia and on the point of returning home, Dr. Smiles informs us that Robert arrived at the port of Cartagena, wearied and waiting for a ship, and while sitting one day in the large, bare, comfortless public room of the miserable hotel at which he put up, he observed two strangers whom he at once perceived to be English. One of the strangers was a tall, gaunt man, shrunken and hollow-looking, shabbily dressed, and apparently poverty-stricken. On making inquiry, he found it was Trevethick, the builder of the first railway locomotive! He was returning home from the gold mines of Peru penniless. He had left England

in 1816, with powerful steam-engines, intended for the drainage and working of the Peruvian mines. He met with almost a royal reception on his landing at Lima. A guard of honour was appointed to attend him, and it was even proposed to erect a statue of Don Ricardo Trevethick in solid silver. It was given forth in Cornwall that his emoluments amounted to £100,000 a year, and that he was making a gigantic fortune. Great, therefore, was Robert Stephenson's surprise to find this patent Don Ricardo in the inn at Cartagena, reduced almost to his last shilling, and unable to proceed farther. He had indeed realised the truth of the Spanish proverb that "a silver-mine brings misery; a gold-mine ruin." He and his friend had lost everything in their journey across the country from Peru. They had forded rivers and wandered through forests, leaving all their baggage behind them, and had reached thus far with little more than the clothes upon their backs. Almost the only remnant of precious metal saved by Trevethick was a pair of silver spurs, which he took back with him to Cornwall. Robert Stephenson lent him £50 to enable him to reach England; and, though he was afterwards heard of as an inventor there, he had no further part in the ultimate triumph of the locomotive. But Trevethick's misadventures on this occasion had not yet ended; for, before he reached New York, he was wrecked, and Robert Stephenson with him. This is the account sent by the latter to his friend Illingworth.

"At first we had very little foul weather, and, indeed, were for several days becalmed amongst the islands; which was so far fortunate, for a few degrees

farther north the most tremendous gales were blowing, and they appear (from our future information) to have wrecked every vessel exposed to their violence. We had two examples of the effects of the hurricane; for, as we sailed north we took on board the remains of two crews found floating about on dismantled hulls. The one had been nine days without food of any kind, except the carcasses of two of their companions who had died a day or two previously from fatigue and hunger.

"The other crew had been driven about for six days and were not so dejected, but reduced to such a weak state that they were obliged to be drawn on board our vessel by ropes. A brig bound for Havannah took part of the men, and we took the remainder.

"To attempt any description of my feelings on witnessing such scenes would be in vain. You will not be surprised to learn that I felt somewhat uneasy at the thought that we were so far from England, and that I also might possibly suffer similar shipwreck; but I consoled myself with the hope that fate would be more kind to us. It was not, however, so, for on voyaging towards New York, after we had made the land, we ran aground about midnight.

"The vessel soon filled with water, and being surrounded by the breaking surf, the ship was split up, and before morning our situation became perilous. Masts and all were cut away to prevent the hull rocking; but all we could do was of no avail. About 8 o'clock on the following morning, after a most miserable night, we were taken off the wreck, and were so fortunate as to reach the shore. I saved my minerals, but Empson lost part of his botanical collection.

"Upon the whole we got off well; and had I not been on the American side of the Atlantic, 'I guess I would not have gone to sea again.'"

Several years had passed after Trevethick had given up the locomotive, before any one attempted to renew the experiment, and it was not until the year 1811 that it was noticed by Mr. Blenkinsop, of Middleton, near Leeds; and, fortunately, from this time the locomotive gradually grew in favour with every one; not, however, without many ugly failures. It was displaced and replaced a good many times. We have arrived at a very trying period, full of interesting incidents, on which hung the very life-breath of the locomotive engine.

CHAPTER IV.

THE RACK-RAIL AND THE CENTRAL CHAIN.

The simple and beautiful engine patented by John Blenkinsop is represented by Fig. 5. The specification was for "certain mechanical means by which the conveyance of coals, minerals, and other articles is facilitated, and the expense attending the same rendered less than heretofore."

The boiler, which was mounted on a wooden frame, had a single wrought-iron tube through its centre; the tube was carried out at the front and turned upwards to form the lowest portion of the chimney. The frame supporting the boiler stood upon four wheels without teeth, and rested immediately upon the axles. This was a novel affair, and it shows very clearly that progress was being made. Then there was a still more startling improvement in the employment of two cylinders instead of one; doing away with the fly-wheel, as in Trevethick's engine. The two cylinders, each eight inches in diameter, were let into the top of the boiler, and in a vertical position, with the slide-bars attached to them. The piston-rods were connected by cross-heads to the connecting-rods, which descended at each side of the boiler, and were joined to cranks which were placed at right angles to each other.

Consequently, the two cranks on the first shaft were horizontal, at their greatest leverage, at the time that the cranks of the other shaft were passing the centres. This is one of the best mechanical combinations to be found even in the locomotive of to-day.

The engine was moved along the rails by means of toothed gearing. The two small pinions on each side of the engine gave motion to a larger toothed wheel, fixed

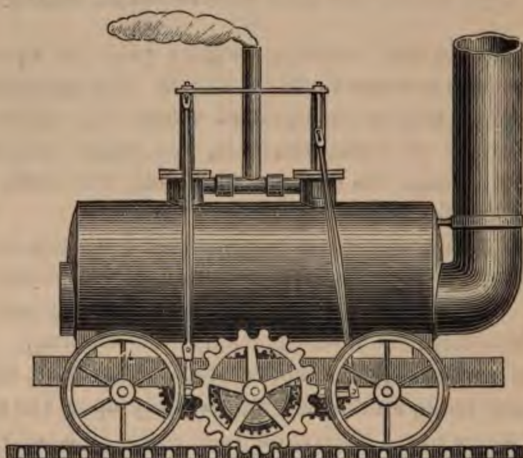


Fig. 5.—Blenkinsop's Engine, with Rack-rail.

on the left-hand side of the framing so as to work into a rack laid along one side of the railway. The piston moved the connecting-rods, the connecting-rods moved the pinions, the pinions drove the cog-wheel, and it gave a progressive moment by rolling in the rack. It was throughout a remarkable engine, but it had one great and damnatory defect about it; that was, that all the driving-power was applied on one side of the

engine. There was only one rack; if they had put two racks down, one on each side of the engine, it would have saved all the expense and grumbling that was caused by the engine breaking the racks, she could not be "off" from it. The power, being applied on the one side only, had a tendency to force the flanges of the wheels against the rails, by which means extra friction must have been produced. By means of the rack, the engine was enabled to draw the heaviest loads that had ever been conveyed, and, with all the disadvantage of making a hundred or two of broken racks now and then, the machine was a beautiful invention. It was a great stride in the right direction. What if there were objections and difficulties? and suppose it was an expensive affair, this engine introduced locomotion in the north of England, where it became, in the hands of a few men, a great motive-power; but it was due to Mr. Blenkinsop's enterprising spirit that the engine in the ditch at Pen-y-darran came again to life. He gave it the breath of life a second time. He was a father to it. He put up with its expensive and troublesome ways, and its failings he covered. Its apparent success determined others to follow in his footsteps. Invention was at work, and amongst others desirous to grapple with locomotive matters, first on the list appears Chapman, who, in 1812, the year after Mr. Blenkinsop started his engine, took out a patent; and patents then were patents indeed, costing about £140. He undertook to facilitate the means and reduce the expenses of carriage on railways and other roads. He proposed to do all this by means of a chain extending along the centre of the railway. The chain was used to pass

round a grooved wheel, or barrel, fixed upon or behind a carriage, so that the engine was dragged along by its turning the chain-barrel. The scheme was clumsy and expensive, and was not regarded with much confidence. Still, there were some good points about it, which, if we mistake not, are worth noticing.

Allusion is made, in Chapman's specification, to a common winnowing-machine to force a current of air under the fireplace. This is the first instance in which a "barn" machine was adopted for helping the locomotive. But the locomotive needed every possible help at that time.

Chapman's boiler, if we are not in error, was different from Blenkinsop's, for it was constructed with a double or return flue, of the type known as the Trevethick boiler. Two vibrating beams were worked by the piston-rods. It was in fact the first locomotive fitted with a beam and parallel-motion. The stationary engine had walked out of the engine-house. One cannot help thinking, after viewing the engine of Chapman, how near Trevethick was to perfection with his first engine, the very first which he brought to London. As we proceed, we shall become more and more convinced that it was a marvel of simplicity. Here we are, ten years later, going no faster, but becoming ten times uglier. This engine was working in December, 1812. There is one other point about this engine, and that is a very important one. The power of the engine was applied through the medium of a train of toothed wheels, under the body of the frame, that was supported by eight wheels. The eight wheels were the running wheels, *with smooth faces.* It is said that these wheels slipped on the rails. Now

Blenkinsop's could not slip, on account of the rack. Then a comparison of the two engines is worth making; and the difference is well worth seeking for. The imaginary difficulty that smooth wheels had not sufficient "bite" was the bugbear that frightened everybody. Here is Chapman with smooth wheels, with a motion all complete to drive them, encumbering himself with a chain and a barrel, to overcome the fictitious difficulty of the want of adhesion between the rail and the wheels. Why, if he had pitched the chain and barrel into the ditch he would have had, in 1812, when his engine was at work, the best locomotive in the north of England. Yes, the best engine in the world. He would, in fact, have had the same engine as Hedley brought out the next year. What proved a stumbling-block to the Chapmans—there were two brothers—proved a nice point for Hedley to decide by experiments. But before going fully into the experiments made by this highly ingenious person, who to a certain extent paved the way for Stephenson, we must notice, in passing, the mechanical traveller, Fig. 6. It came out in 1813—dates are of great value. The contriver was Mr. William Brunton, of the Butterley Iron Works, in Derbyshire. It consisted of a combination of levers, the action of which resembled the legs of a man when walking. The single cylinder was placed horizontally on the boiler, and the piston was attached to a leg, with a loose foot jointed to the leg. By the front stroke of the piston-rod, the leg being firmly fixed, the engine was moved ahead, dragging the other leg into position ready for the return stroke. This part of the contrivance strongly attests the ingenuity of the contriver: by referring to the drawing

it will be seen that on the lever *a b* a rod, 1, 2, 3, is attached, running out upon the top of the boiler. From 2 to 3 it is fitted with teeth, which work into a cog-wheel. Working horizontally on the opposite side of this cog-wheel, a sliding rack was fixed similar to 1, 2, 3, which, as the cog-wheel is turned round by the sliding rack 2, 3, was moved backwards and forwards. To the end of this sliding-rod was fixed the other lever *d e* at 4. When, therefore, the sliding rack

Fig. 6.—Brunton's Locomotive.

was moved forward in the direction 3, 2, 1 by the progressive motion of the engine, and when the piston-rod was at the farthest extremity of the stroke, the leg *d e* was brought close to the end of the boiler; the piston was then made to return in the opposite direction, moving with it the leg, *a b*, and also the sliding rack 1, 2, 3; the sliding rack, acting on the toothed wheel, caused the other sliding rod to move in the contrary direction, and with it the leg *d e*. When-

ever, therefore, the piston was at the extremity of the stroke, and one of the legs was no longer of use to propel the engine forward, the other, immediately on the motion of the piston being reversed, was ready in its turn to act as a fulcrum, or abutment, for the action of the moving power to secure the continued progressive motion of the engine.

The boiler was of wrought iron, 5 feet 6 inches long, and 3 feet in diameter. It was "cracked" up to bear a pressure of 400 lbs. per square inch. The cylinder was 6 inches in diameter, with a stroke of 24 inches.

When the engine was being tried the driver got drunk, and, owing to the pressure being too much for the boiler, she flew all to "bits" and killed him and two or three others who were standing near; scalding a dozen or more folks most severely, and frightening many others nearly out of their wits. If this engine could properly have been called a locomotive, she would be said to have been the first to blow up.

CHAPTER V.

WILLIAM HEDLEY AND THE PLAIN RAILS.

WE will now retrace our steps to Wylam, on the Tyne. In connection with a colliery there, the property of Mr. Blackett, a man of considerable engineering ability, there was a railway, characterized by severe undulations, worked by horses. At one time wooden rails were used on the line, and the horses drew one waggon each. About the year 1808, cast-iron plate-rails were substituted; then one horse could draw two waggons.

The interest does not centre so much in the horses, or the waggons, as in this particular line of railway itself; a railway immortalised by accident, where the locomotive was to be baptized. The locomotive received a name here and a local habitation; and it was here that it established its right to existence, and to be improved, and helped on to maturity. To explain how this happened is our next business.

Trevethick was written to in 1809 by Mr. Blackett, who had met him in London some time before. The subject of the correspondence was a locomotive engine. Trevethick, in reply, stated that he was too busy, and he declined all "truck" with the "thing." He had had enough, no doubt, of locomotives in South Wales.

But this was not all, for Mr. Blackett, as early as 1804, obtained the drawings of an engine from Trevethick, and took them to Gateshead, where he expected to repeat the Pen-y-darran performance in the north. Trevethick's engine was in the ditch. Well, the mechanics in the north, with native pride, "chuckled" over the new engine as it progressed towards the finish; but, alas! it was born under the wrong planet. The rights of the story were never told. All that was ever known outside the foundry gates was, that it ran for a little within the gates, but proved to be worth nothing. It never ran outside the yard. Its nose was put up the tuyere of a cupola at an iron foundry in Newcastle, and at "blowing" it appears to have done very well. It is not a matter of surprise that Trevethick said "no" to any more locomotive business: he could see his favourite in a ditch, and another child of his with its nose in a Newcastle cupola. His was a cruel fate. Mr. Blackett, not having got a satisfactory answer from Redruth, applied to the most eminent engineers of the day, who told him that the idea of an engine to draw coals was chimerical, physically impossible. "Look," said they, "at the fate of the locomotives in South Wales!"—supposed to be sufficient evidence against locomotive power.

Nothing was done; but the price of hay and corn went up in 1811, and colliery proprietors looked around them.

The war continued, for Napoleon was in the saddle, and England on the watch. So, to economize in such times was the only way to get along, and everybody had the option of carrying out economy according to his own views. At the Wylam colliery they tried to

replace the horses on the railway. What? with locomotives, of course! No. Bullocks? Yes; with bullocks. They were shod with iron, and worked for some time on the railway. The creatures were docile in harness, cheaper than horses, but after a short trial it was decided to turn them into beef-steaks. But there was one redeeming feature in this experiment, and that was, the bullocks were sold for more money than they had cost.

The use of horses was ruinously expensive, and the construction of an engine to convey the waggons on the railway as a substitute, became more and more the question of the day. No one knew this better than Mr. Hedley, the mining engineer at Wylam colliery, and the subject was constantly present in his mind. He must have known what others had done. There was Blenkinsop of Leeds, with a rack-rail engine, and there was Chapman at Newcastle, with the endless chain and winding-barrel apparatus. These were certainly not very promising inventions, but he may have questioned whether or not either of them was the right thing, and we may, from what afterwards took place, assume that he doubted whether they were. What was the aspect of affairs? Blenkinsop's engine did not suit him; the system of the rack was excessively costly to lay down, and expensive to keep up. Chapman's engine worked with a chain which frequently broke, and although the engine had been working but for a short time, it had sunk nearly £3,000 as effectually as though the money had been thrown into a well. Very well, such were facts. How did Mr. Hedley act? He knew that all this bad luck was caused by errors of principle. It was not the boiler power, nor was it the

engine, but the evil lay in getting along so extremely badly; and it was this that brought up the working cost of the engine almost on a par with the cost of working the line by horses' power. Under such conditions, who would run the risk of being blown up into the air by using locomotives, when there was no economical advantage to be gained. The Wylam colliery-viewer turned the subject over in his mind, looking first at the rack-engine and then at the chain-engine, until it occurred to him that it might be possible to dispense with both systems. At least, he thought so, and he would try it. Try it he did, at Wylam; the date is given as October, 1812, when his experimental carriage was placed upon the railway. The object of this experiment was to prove, and, as it turned out, to settle for ever, that Blenkinsop's rack and Chapman's chain could be thrown aside. It was exactly the kind of test one would expect to see made at that time, nothing could be more in keeping with the question of the hour. Hedley was the man; Wylam the place; October, 1812, the time. Accordingly a carriage, Fig. 7, was made at Wylam under the superintendence of Mr. Hedley, for the purpose of deciding the fact "that the friction of the wheels of an engine-carriage upon the rails was sufficient to enable it to draw a train of loaded waggons." This experiment was conducted with great care, tested thoroughly, and the result was to prove that the friction of the wheels of the experimental carriage *alone* upon the rails, when it approached in weight to an engine-carriage, was sufficient to enable it to overcome the resistance of an attached train of carriages. The experiments extended over the whole line, commencing at Wylam and ter-

minating at the Tyne, a distance of five miles. Fig. 7 is a representation of this test-carriage, or engine-frame; the latter is the more fitting term to use, because a boiler and engine were afterwards applied to it. The frame was supported by four wheels, and acted upon by means of spur-gearing. The body of the frame was loaded with "pigs," or parcels of iron.

By the application of windlass-handles on each side of the frame, a result was obtained of the utmost importance in locomotive science. As above mentioned, the frame was loaded with iron equivalent to having an engine and boiler placed upon it, and the usual motive-power, namely, steam, was represented by the muscular

Fig. 7.—Hedley's Test-carriage.

force of four men at the handles; but this number was occasionally increased when an additional load of waggons was hooked on. Everything was properly weighted, the number of waggons hooked "on" and "off," and the amount of slipping properly recorded. Altogether the result was most satisfactory, and was a most interesting achievement, as it established the true principle of locomotion—gravity, the only motive-power in the world.

As might be expected, Mr. Blackett felt that he was on sure ground, and he thought that an engine and boiler should be placed on the experimental frame. What

could be better? The test was perfect, and had not Mr. Robert Hawthorn seen it and approved of the principle? It was determined that Mr. Blackett's idea should be carried out, and an engine and boiler were put in hand, in the building of which, in those days of primitive engineering, great difficulties were experienced. Many times, in the course of construction, they were just about as far on Wednesday as they were on Monday; but the "iron horse" grew slowly.

The boiler was of cast-iron, cylindrical, having a longitudinal tube through the centre, leading to the chimney, which was situated at one end, whilst the furnace was at the other end. The engine had one cylinder 6 inches in diameter, and a small fly-wheel to help it over the centres. The boiler was loaded to the pressure of 50 lbs. to the square inch, a pressure which at that time was "talked about." Talking about steam, amongst the collieries at some distance from Wylam, if a brakesman "cracked" on about the pressure in the boiler which worked his whimsey, he was met with a challenge to go and see "Trevethick's patents" that carried 50 lbs. steam.

But this engine did not go well for want of steam, and, to try and make it a better engine, a second cylinder was added; with no better result, of course. The weak part of this engine was the boiler; the radical defect was an insufficient supply of steam. Unfortunate as the want of steam was at the time, the question was decided, nevertheless, that the adhesion of the wheels of the engine upon the rails was sufficient to produce a progressive motion in the engine when loaded with a train of carriages, without the assistance of the rack-rail or the chain-barrel. Great credit is

due to William Hedley for *this* discovery, this great discovery. He was confident that the principle was right, and he exhibited not the slightest degree of indecision, but was resolved to try again. Make another locomotive? Yes; that he would, and sure enough he did. His next engine was a success, and excited great interest throughout the mining districts. The engine is now in the South Kensington Museum. People from all parts came to see the iron and steam horses, which were called by the workmen "dillies." The boiler of Hedley's second engine was of wrought iron; and, in designing it, he felt the necessity of increasing the heating surface, to obtain a sufficient supply of steam. At the same time, he had to limit the weight—a point of importance where the railway was "rickety." At the time to which we refer, the rails at Wylam colliery weighed 36 lbs. to the yard.

The stability of the line has always been a perplexing question with locomotive engineers, in consideration of which they are not unfrequently cramped in maturing the mechanical arrangements of an engine. The road is, on some lines, fully a quarter of a century behind the requirements of the time, and the rails look like bits of wire under a 60-ton or 70-ton engine. If the weight and speed of the trains demand the employment of an engine of that kind, the road should first be fetched up to a high state of efficiency. The engine is, in some instances, ahead of the road; whereas the road should be in advance of the necessities of the engine, leaving a margin for the constantly increasing weight of the rolling-stock.

Mr. Hedley thought of two methods of increasing the

supply of steam, which prove that the business was in good hands.

According to the first method, after the tube containing the fire had passed to the end of the boiler, he proposed to return the tube back through the boiler before terminating in the chimney, thus making a return or double tube.

By the second method, after the fire-tube had traversed the boiler, the heated products of the furnace could be divided, making two flues for the return in place of one.

He took time to consider the matter, and at length determined on applying one oval return-flue through the boiler; a plan that would present much more heating surface than his first boiler, and one that would absorb much of the heat from the products of combustion that had hitherto been lost in the chimney. In the single-flue boiler the chimney used to be red-hot, and when the engine was puffing and snorting away on a dark night, this "head-light" would shine with the brilliancy of a meteor.

It is stated that the "Black Billy's head-light" frightened a man at Newburn out of his senses so much that he "made" through a hedge, and, calling on the first person he met to listen, narrated how he had seen a terrible "devil" on the road.

After some trouble in finding qualified workmen, and taking down this and putting up that, a contingency which usually happens with new work, the boiler was finished. The engine was at first placed on four wheels, and it gave general satisfaction.

The fuel used for generating steam was of a rough description; whereas, in the first engine, nothing would

do for the driver but the very best coal. The great economy was manifest, and it no doubt proved a sponge to wipe out many a black score at Wylam colliery.

Shortly after the new engine commenced working, it was placed upon eight wheels, as the railway was too weak to support the weight upon four wheels (Fig. 8).

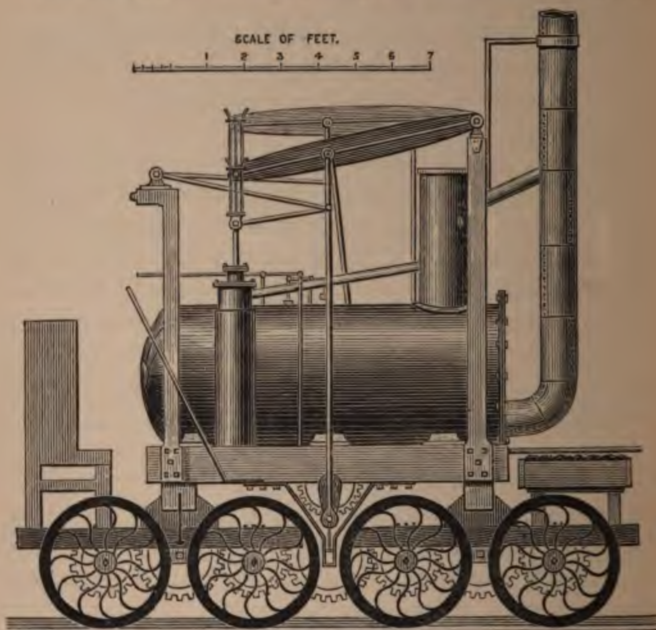


Fig. 8.—Hedley's Engine.

The gauge of the railway was 5 feet. This engine was, as we may be sure, a great novelty, and it made a noise in the world: sufficient, at all events, to be heard at a colliery hard by, and so loud as to induce the owners to make an engine like it, of which more shortly.

The second engine at Wylam, by its practical success, set aside rack-rails, chain-barrels, and movable legs. It brought locomotive science nearer to the true principle than any other engine before it had done; but there was one thing in this engine that stopped just a little bit short of the exact point, and after we have dealt with it we shall then investigate the doings at another colliery, quite as extraordinary as the doings at the Wylam colliery. In the building of the second engine at Wylam, provision was made for the purpose of quelling the noise of the exhaust steam, which, in the first engine, was discharged into the atmosphere. The plan made use of was simple and good, namely, to blow the exhaust steam from the cylinder into a condensing-box on the front part of the boiler, whence the reduced steam was allowed to escape through a pipe into the chimney.

The condensing-box had the effect of putting an end to the noise of the exhaust steam when it escaped from the cylinder direct into the atmosphere, but could create very little draft on the fire, and the arrangements were totally opposed to produce such an effect, since the exhaust steam from this pipe blew across the line of the draught in the chimney. That it had a sensible effect need not be doubted; because Mr. Hedley, some time after the condensing-box and pipes to the chimney were in operation, is stated to have had the end of the pipe altered with its end vertical in the chimney. This was an improvement, yet still the exhaust steam was passed through the box to reduce its pressure and temperature. That the pressure was reduced, there is the evidence of the "condenser" on the boiler to wit.

We will now take our leave of the Lorraine engineer Cugnot, Murdoch, and Trevethick; the same of Blenkinsop, Chapman, and Hedley, and will proceed to consider the works of Stephenson, the seventh champion on the roll.

We have some dim notions about this mystic figure seven, but have not space to record them. We may with the poet say—

> "I have wandered in the mountains, mist-bewildered,
> And now a breeze comes, and the veil is lifted,
> And priceless flowers o'er which I trod unheeding,
> Gleam ready for my grasp."

We pass from Wylam to classic Killingworth, to see the celebrated man that was to become prosperous and famous by means of the locomotive.

CHAPTER VI.

GEORGE STEPHENSON.

Now and again a man appears on this world's stage charged with a noble mission. Like Elijah the Tishbite, inspired and, to all intents and purposes, told off by Divine Providence to carry out some great work. Such is George Stephenson—George Stephenson the Killingworth Engineer, George Stephenson the Immortal!

Great things did this man do for the century adorned by his name: his genius has inscribed his name indelibly upon its history.

As we have faithfully traced the progress of the engine, it was not necessary, up to this point, to make mention of the name of Stephenson, since he had no connection with the locomotive until some time after it was put to work on the Wylam Railway under Mr. Hedley, who made the way for Stephenson, and gave him a good start at Killingworth.

In the year 1815, Stephenson thought of building an engine. His brain was equal to the undertaking, for his head was like a storehouse or a carpenter's shop, from which he could readily take what he required, and apply it to the best purpose, or shape it as he liked.

For several years he had watched the working of the Wylam engine, and he had an idea that he should like to make one for the Grand Allies, the owners of the Killingworth Collieries, where he was employed. Could he do this? Had he the necessary qualifications? Let us see. At Wylam he first saw the light on the 9th of June, 1781, a hundred years ago (Fig. 9). The son of Robert Stephenson, who described him as being like a "peer o' deals nailed thegither, an' a bit o' flesh i' th'

Fig. 9.—Birthplace of George Stephenson, at Wylam.

inside; an' war as queer as Dick's hatband—went thrice aboot an' wudn't tie."* The wages of George Stephenson's father were never more than twelve shillings a week, being a fireman at a colliery, and therefore the lad had to turn out pretty early in life. He began, like a good many country lads, by tending cows in the lanes, filling up the time stoning water-rats, climbing trees after nests and skinning the bark

* Smiles, "Lives of George and Robert Stephenson."

off his shins; but his favourite play, we are told, was making "Liliputian mills in the little water-streams that ran into the Dewley bog with steam-pipes made of hemlock." From this he went to the plough, leading the "leader." He was subject to all the changes of employment incidental to farm-house life. But he liked his father's business best, and he watched every opportunity to find employment at the engine-house.

The smell of oil in his dad's clothes was to him the finest aromatic perfume, and to wipe his hands with "waste" from morn to dewy eve at a colliery whimsey his sole ambition. As all things come to those who wait, so the time came to which for years he had looked forward, and after having driven a gin-horse for a time, he was engaged at Dewley to fire the boiler when he was fourteen years of age, and his pay was six shillings a week. Jim, his brother, was also a fireman.

Shortly after this, George went over to the M.-M. W., or Mid-Mill Winnin Colliery, and fired there for two years to a "wheezing, sighing, creaking, and bumping engine;" but, at the same time, events were casting their shadows before. Instead of spending his spare time in the ale-house, he was preparing himself to take higher wages. His social habits were those of a man whose sole ambition was to comprehend all about the routine of an engine-house as well as a stoking-hole. He wanted to rise, and rise he must; and therefore it is not surprising to find that this man's leisure hours, spent in acquiring practical knowledge, should have turned out so remunerative. Whatever a man soweth, that shall he also reap. Stephenson at this time was working twelve hours a day firing; he had been doing so for some years, but in a short time he became plug-

man at the Water-row Colliery, and his father was fireman there at the same time. George lost no time, but buckled to, improving every minute of his spare time to learn two things: his letters, and how to brake an engine. Occasionally he received a lesson in the art of brakeing, and by practice he learned the art. In 1801, he obtained the appointment of brakesman at the Dolly pit, with a day and night shift, and "a standing example of manly character" he was. He hired a cottage dwelling, and at the same time he married Fanny Henderson at Newburn church, on the 28th of November, 1802. With his wife and his occupation as brakesman at Willington, and a bit of garden, he was rich. But his marriage cannot be passed over without our hearing the account of it given by Mr. Smiles. After the pair had been married at church, "the bridal party set out for their new home at Willington Quay, whither they went in a manner quite common before travelling by railway came into use. Two farm-horses, borrowed from a neighbouring farmer, were each provided with a saddle and pillion, and George having mounted one, his newly-wedded wife seated herself behind him, holding on by his waist. The bridesman and bridesmaid in like manner mounted the other horse; and in this wise the wedding party rode across the county, passing through the old streets of Newcastle and then by Wallsend to Willington Quay." Such was the great locomotive engineer's marriage, just about the same time that Murdoch frightened the parson with his locomotive at Redruth in Cornwall.

At this time, he was pulling hard against the stream; —occasionally mending clocks for the neighbours and

diligently studying the principles of mechanics. Anyhow, so long as the elements that enter into the construction of the various parts of machinery were impressed on his mind, he was satisfied. We feel that these minute details are imperatively demanded; for it must be remembered that, with all homely and rude surroundings, we are dealing with a candidate for fame, and with a man whose name is illustrious, so that every turn in his daily calling is deservedly interesting. It is all history, every bit of it. We may try to deceive ourselves that it is ordinary narrative, but in vain. Look on the marriage scene thus described, and then on the man of after years, in the zenith of fame, and it is impossible to feel indifferent. The ground on which we stand is full of love. The incidents of his early life are more astounding than the fancies of even Eastern poets. Perhaps in the whole history of biography, in the history of one man's life, it never did occur for the last to be first and the first last. But he was the last to take up with the locomotive, and the first to triumph in its achievement. He was the last in the field, but the first to win the prize. He was the last to try, but the first to succeed. He was the last we should expect to rise to fame as a locomotist, but the first to obtain it.

We will return to Willington Quay, where, under many adverse conditions, he studied mechanics; not from books, for he possessed none, but by taking the clock to pieces and by disconnecting various parts of his engine and putting the pieces in their places again. By such means countless items of information were gleaned; a knowledge of the mechanical powers, or the elements of machinery, one by one, was acquired by

his inquiring mind. He was doing real work; encouraged to persevere solely out of love for the subject, and, prompted by the reflections of how well he had so far succeeded, he pressed onward. The devoted husband: the young engineer. The unfolding of his mind is little short of the marvellous, seeing how much dead weight there was on the surface. In this fact we see matter for congratulation; his origin and its surroundings are so much as ours are, that they send us again and again back to resume our struggles in pursuit of our favourite enterprises, and with a will. We would counsel all who wish to succeed, or who require now and then the example supplied by some stimulating piece of biography, to lift up and to sustain their weary hands, to read the life of George Stephenson.

There is no sham in the history; its stern life seeking no higher approval than that to be found in the consciousness of "moving on," rejoicing in hope; genius in contest with rugged nature, hewing and shaping the "stone" for the wall which sooner or later it will have to adorn.

Here is a man, though only a poor brakesman, practical, in all simplicity goes hand-in-hand with his "adopted," rising to fame. Willington Quay became too small for his ambitious spirit, and having been offered a situation at West Moor colliery, similar to that which he held at Willington for several years, he accepted it. But soon after his wife died, and while grief was still on him he left West Moor and went to Scotland, to take charge of a stationary engine at a large spinning-works, near Montrose. He did not remain long there, but returned to Wylam, footsore and wearied. He started again at the West Moor pit

as a brakesman. He had been further away from home than he had ever been before; he had learned what it was to be on the road, and to feel the weight and oppression of cruel circumstances. He was afflicted and made acquainted with grief, and was not, by God's providence, allowed to escape the "fire." He had scarcely embraced his little son Robert, and visited the grave of his lost wife and daughter, than he was drawn for the militia, and in the anguish of his heart he wept bitterly on the road between West Moor and Killingworth; "for it tried my heart," said he, "to leave my home and my boy, and the scenes of youth and the friends of boyhood. I wept bitterly, for I knew not where my lot in life would be cast." He was by providence—and luckily for England that Robert was born—prevented from drinking the "cup," which to him appeared to be full of bitterness, by having a friend in the time of need. There was no alternative at that time but to "go a-soldiering" or pay. He hadn't so much; his savings would not "run to it," and what was to be done? Had he not been a dutiful son, a dutiful husband? and did his heart not yearn for his boy, and yet this cruel fate falls like a thunderbolt to quench his spirit, and finally defeat his aspirations. "I wept bitterly," said he, and we doubt not the big tears scorched his cheeks.

But man's extremity is God's opportunity; and as it is only when we are fit to live that we are most fit to die, so it is only when we feel most weak that we become most strong. Our inward strength is then almost startling. He had his gracious moment. Stephenson went—dare we say by inspiration?—to a friend who lent him some money, and thus assisted him through

one of the most eventful passages in his life. In the year 1808 this occurred, and he was twenty-seven years of age.

Soon after he was delivered of this trouble, prosperity smiled, and we find him at West Moor, claiming to have made considerable saving by reducing the friction about the pulley-wheels of the winding gear. His individual character was just developing, and who can tell what part the painful past had in effecting this? Traces of such ordeals sometimes go half way through life, and not unfrequently turn the course of many a life; sometimes the fatal self-consciousness of having been in the "fiery furnace" deters the sufferers from looking abroad. They become forlorn and dejected, and loath to approach the fire again which burned them. For ever after they confine themselves to the humbler walks of life, and leave to others the next act. It was not so with Stephenson; he put on *more* armour, and all might have seen it. He was a brakesman still, but he was now a man who could overpower every impediment in the way of his mastering the details of the engine. The dross had been burnt out of him in the past, and the fierceness of the flame enabled him to say triumphantly, "For this relief much thanks." George Stephenson acquired influence with his fellow workers; they knew his strength of purpose, the ardour of his zeal, the enthusiasm and courage with which he fought the wrong, and by which he maintained the right. Every line in the chapter of his life shows that they were not deceived. He did not altogether rely on his own self, he knew that self was weak.

> "Yet thoroughly to believe in one's own self,
> So one's own self were thorough, were to do
> Great things."

But he committed no such foolishness: "cobbling shoes, figuring, and brakeing went on together," but he could see no inconsistency in one moment pointing out the faults in an engine, and in the next the mercies of Divine Providence. He was not an effeminate ascetic, neither did his views of religion overpower his good sense; but he was not so small a man as to do on Sunday what could be and might be done on Monday. Such a test of his principle once occurred. The "Grand Allies," neighbours, had one of their pits drowned out, and they could not get the pumps to "throw" properly. George had casually expressed his opinion, as men with opinions to express will do, without being asked, that the engine was defective, and that he could alter her. This was reported to head-quarters. What was Stephenson's opinion? he was only a brakesman at West Moor. Such sneering touches are very often the marks of little minds. Rare souls do not easily give vent to such utterances, levity of the cheapest sort, to try unblushingly to depreciate unduly and untimely another experience. Very few dare to disregard the justice of giving even the worst enemy a chance to prove himself right.

The water continued to rise in the pit until it began to be noised about that the engine was a huge failure; and they might have added another great failure—the failure of the brakesman to find out the cause of the failure. Altogether, the affair looked much to the disadvantage of the viewer. Sunday morning came, and the scene at the pit was not creditable to any one. If there was any superior skill in the district it was surely wanted at the High Pit, to unwater the mine. What could be done? Hadn't Stephenson said he could alter

the engine? Why not break through false pride, and call him in? The feelings of chagrin, of disappointment and pain, have no weight in the presence of real danger. When the ship is on her beam-ends through the cargo shifting, what does it matter who removes the danger? By Sunday evening the water gained so much that it was contemplated fetching Stephenson, and so the head viewer left the pit with that intention, and, falling in with him dressed in his Sunday's suit, on the way to the preaching in the Methodist Chapel, he wanted George to go and have just a look at her. But no, he would not. It was Sunday. "But to-morrow morning I'll set to work, as I think I could put her right."

The next morning the engine-doctor arrived, and in a short time the water was got away. No one was better pleased than Stephenson. The real value of this cure—this effectual cure—might lead to something some day. He had exhibited throughout his whole career a desire to excel, and had employed all his spare time in the study of the principles of mechanics, and he was slowly but surely going the right way for promotion; which came sooner than he expected, owing to his having freed the High Pit of water. The viewer gave him ten pounds and made him engine-man at that very pit. A brief consideration of the task which he had to do, in bringing about his rapid promotion, supplies the best criterion of his capacity. This phrase must be taken to denote the resources that at that time lay dormant within him. Whatever ingenuity he may have displayed in clearing drowned-out pits, it requires no persuasion nor pleading to prove that his power was founded upon his thorough study of the science of

mechanics. Such an one is never lost for an explanation; he no sooner sees his patient than he prescribes the remedy. The ability which Stephenson brought to the service of the Killingworth party was backed by a thorough command of circumstances, which helped him all through life. He was masterly in device, he was fertile in expedient—qualities most needed at Killingworth; and it was in these that the strength of Stephenson lay. He need not have had much difficulty in proving to his party that they had to "send" for him. He made it more effective. He knew that real worth was seldom acknowledged, and that only by a daring license it was called "clever." But he knew himself and bided his own time.

Suppose that, after clearing out the pit, he had followed a train of thought something like the following, that took place near London:—Driver A was discharged for allowing his engine to run away, with the fireman asleep on it, with a passenger train. After an interval he was again employed in a lower grade as fireman, in which capacity he served for a time, and was made a driver at the lowest pay. Circumstances compelled the foreman to give him main-line work. He ran a trip, and thinking the "time" had arrived, he waited on his foreman next day. "Sir," said he, "I ran main-line yesterday." "I know you did," said the foreman; "what by that?" "Why, I want to know if I am going to have main-line money, sir." "Hold on," said the foreman; "before you get the whole of the sentence out, let me inform you that the train you work is knocked off to-morrow, so your professional services are no longer required; and, before you leave me, allow me to tell

you that a man's capacity is like the strength of a chain, the weakest part is the measure of its maximum strength, and you should never forget that."

In 1812, four short years after, Stephenson borrowed money to get clear of the liability to serve in the militia, over which the big tears rolled down his face, because his way was hidden from him, and because he knew not how his life would be cast in the future. In 1812 he was made engine-wright to the collieries leased by the "Grand Allies." We cannot refrain from noticing the chain of events, and we have endeavoured to trace them up to the attainment of the object which crowned his destiny. Hedley, at this time at Wylam, was getting Mr. Blackett's second engine built by Foster, the engine-wright there. The whole period of his acquaintance with the engines stretches over an interesting era. He had been for years the architect of his own intellectual edifice; at one time his thoughts were wandering here and everywhere, now he could concentrate them on any one particular thing that claimed his attention. Yet more, he had learned the method of storing information, and one special feature in his daily life was to contemplate every new fact in the same light as an astronomer regards a newly-discovered planet. Living as he did amongst fly-wheels, brakes, and boilers, with a special passion for engineering, the engine-works grew with him rather as an instinct than a science, and continued through life the delight of his latest hours.

The scenery he liked was "set up" by Smeaton, Watt, and Hawthorn.

He liked nothing better than the steam-engine, and his enthusiastic love for its development grew with his

growth, and he was credulous enough to think that he could "do" with a locomotive at Killingworth. By all means let him try; but, at this stage, impartiality compels us to insist that the doings of the Wylam people should receive their due meed of appreciation.

It was to them that Stephenson was at first indebted for everything pertaining to the locomotive, and as locomotives had been working, and had passed him on the road, close to his home, he had every opportunity of making himself thoroughly acquainted with what they could do and what they could not do, before heating a rivet for his own engine. The cause of the locomotive had lain close to Hedley's heart, and exercised Hedley's brain long before Stephenson joined the cause. Hedley had wandered in the mist, but now the veil was lifted, and the "flower" was above the bed's head gleaming ready for the grasp. The ardent soul of the Killingworth engine-wright yearned after the locomotive, and his mental struggles are portrayed in the visits that he occasionally paid to Wylam to talk with Jonathan Foster on the spot.

These frequent visits were of a friendly nature, but we all know it ended in making him the foremost of English engineers.

The strains that struck the heart in after years, when the hopes and dreams were more than realised, were ten thousand times less likely to scare him into dreaming than was Foster's story of belly-stays leaking in the Black Billy.

All the salient points of the engine were carried away to Killingworth, and after mastering all the arrangements, the task of making an engine forced itself upon his attention day and night.

But *he* had never constructed an engine; hardly was he in a position to lead the "Grand Allies" so far as to induce them to yield. What argument could he advance to move them to speculate in locomotives? Had he any clenching fact to lay before them, showing that locomotives "paid"? He knew nothing except what Foster had divulged; but true, Foster was an intimate friend, and it was well for him—and England—that he was. It is not either to be thought that Foster, an employé of the Wylam people, would be found encouraging Stephenson to compete with his employers. But it was extremely annoying to Blackett and Hedley to hear of George Stephenson's frequent visits to the Wylam railway. For what purpose were these visits made? There could be but one answer. To see what the engine was like; to find out what the engine did; to hear what was considered their weak points. His mind could readily lay hold of and understand any good feature, and it was equally ready to detect a bad feature. He had so abstracted his mind as to fix it solely on the engine, and he could not get "off" from it; and therefore he went before the "Grand Allies" and pleaded the cause of the locomotives.

The system of hauling coal by engines instead of horses had been denounced as an absurd innovation, and many stories circulated about Killingworth and elsewhere particularly damaging to their reputation; whilst all the colliery people were, to a man, hostile to them, and they embraced every opportunity of running down the engines. Why, one had blown up and killed many folks; and the proprietor of a "way-leave" had threatened to shoot the driver. People had a hard task to make both ends meet as it was. How would

they manage if the engine were established? The topic was an unpleasant subject everywhere, and the "Grand Allies" were not prepared to run after ridiculous notions. The collieries were now quiet and prosperous, but this madcap engine-wright might raise a storm that not even the "Grand Allies" could quench, without "sinking" a lot of money. The place might fall into a state of siege—one of the most unpleasant conditions imaginable in which a firm of irreproachable character can find themselves called upon to abide. They could now walk quietly about their "fields," without the startling sensation of being fired at by some drunken fool, labouring under some imaginary grievance, brought about by the locomotive.

Stephenson had before given utterance to his sanguine speculations as to the *Travelling Engines*, but the firm had a certain amount of timidity which had to be respected by one in his position. There can be no doubt that the caution exercised had been fully justified by past events at Wylam.

But nothing would dissuade the Northumbrian engine-wright from thinking that there was a good "thing" at Wylam, and that he would like to see a good thing at Killingworth. And Killingworth should. And Killingworth did. He who can take up and adequately describe all the rich endowments that have followed to this country upon that, deserves to be called a master. Man required a locomotive. God found the man to make one. Necessity was the prime mover, and to provide for it all things must conform. Want does all things; it builds the world, builds the railways, bridges, and rivers; builds harbours, opens public ways, builds temples. We cannot find another

incident in the history of all time so deeply fraught with interest as that of George Stephenson receiving orders to build an engine from the "Grand Allies" for Killingworth Colliery. Great drawbacks there were, but Stephenson was a countryman that could face them. He had confronted difficulties before, and knew nothing about defeat. He had courage to persevere, and that was in itself sufficient to rout a host of foes. We read of battle-fields famous in history, immortal in fiction. But the coal-fields of Killingworth, are they not famous? On this ground we are spellbound. Hark! hark how the anvil sounds, stroke follows stroke, flash, flash. Sons of Vulcan. Forgers, forging an "iron horse." Strike, men with bare arms, craftsmen, strike! Strain, men with bosoms bare! Finest forgers, strain every nerve! Strain! strain! Down, men with dishevelled hair. Finest hammermen, down, down on the hissing mass, down! See the molten lava pouring from his sides. Flashing sparks hurl with iron force their red-hot sides against the smithy wall. Albion's smithy. The roar increases. The village resounds. The thunder of the anvil shakes the ground. Flying hammer-men, fly! The monster shudders, the blood toils in his veins. Seize, finest craftsmen, seize! seize this fiery Northumbrian "horse,"—monarch of speed.

CHAPTER VII.

GEORGE STEPHENSON'S FIRST LOCOMOTIVE.

HAVING been commissioned to make a locomotive, he applied himself to the task. Little did any one think at that time what a marvellous stride he was going to make in the construction of the locomotive engine. He commenced at once. The faults and the merits of the Wylam engines were alike laid open, and with a select conclave of his associates, all was done above board. It was a simple talk that they had, and yet the consequences and results baffle and beggar description. Stamp it with language? It cannot be done. We stand amazed, and looking in any direction we will, the number of benefits flowing from this one man joining himself to the locomotive cause has no parallel in history. We must not forget the tools he had to start with; they were very limited indeed, and skilled workmen were like parish churches, only one here and there. And then engine-building was a newly-created art accompanied by many difficulties, much putting up and pulling down before the machinery gave anything like satisfaction.

But he had a better chance of succeeding than any man before him, for it was his privilege to begin where his predecessors had left off.

And it is not by any means a difficulty to show and establish the fact that he did profit, and very much so, by inspecting the works and discoveries of others, just as others had done before him, and it is right that he should have been expected to produce a good engine. He was intensely fascinated and interested in the progress of the engine, and on one occasion he expressed himself in a way not at all inclined to lead his hearers to think that the engine was perfect. It came with good-humour, no doubt, but it was a bold opinion to hold that he could make an engine to go upon legs, and then be better than any he had seen working; and this expression was the subject of much curious speculation in the colliery districts.

The locomotive engine had already been invented, six individuals had before him experimented upon it, the last of whom was Hedley, and he had made an efficient and economically-working locomotive engine. What were the revelations, then, that placed Stephenson in the front rank of locomotive engineers? It was not the employment of steam; Papin had employed that for driving machinery a century ago. It was not the invention of the locomotive, for we have proved that it was introduced before his time.

We have, therefore, before us the task of tracing Stephenson's part, and of showing how he accomplished it.

It was an extraordinary undertaking, but Stephenson had studied the improvements of others, and formed plans for introducing improvements of his own. He started well. And the chief operating cause in his success was having at his back the "Grand Allies," —money! money!—and the firm ready to acknow-

ledge that special advantages were attached to the trial from a speculative point of view. The services thus rendered to the country by this spirited undertaking of the "Grand Allies" should be immortalised in English history.

It is an interesting reflection that they gave their consent to adopt Stephenson's plans with a feeling of simple admiration for his practical talents. It was through them that the application of steam-power to work the colliery railways received at this time a fresh impulse. Had they neglected Stephenson's suggestions, the days of the "rapid car" would not have reached us, and sixty miles an hour would have been an unknown feat. Indeed, what the consequence may have been is hard to tell, but we may be sure that we should be hearing a good deal about "Lunnon" yet, and less about London.

At the opening of the Newcastle and Darlington Railway in 1844, Stephenson said: "The first locomotive that I made was at Killingworth Colliery, and with Lord Ravensworth's money. Yes, Lord Ravensworth and partners were the first to intrust me thirty-two years since with money to make a locomotive engine."

He began the construction of the engine at Killingworth in September, 1813. The boiler was made of wrought iron, cylindrical, with hemispherical ends; and the furnace, or fire-tube, was merely a tube passing longitudinally through the boiler into the chimney. The tube was 20 inches in diameter, and was turned up at the front end to form the lower portion of the chimney. The chimney was also 20 inches in diameter and parallel throughout.

The part of the tube in which the fire was placed was occupied by the masonry and fuel to an extent approaching two-thirds of its sectional area. An angle-iron ring surrounded the furnace at the back, to which the door was attached. It was to all intents and purposes a boiler of the most modest description, and the heating-surface necessarily very limited.

The works of the engine were also of a very unpretending character, but the design was novel, and that was a "long" stroke in Stephenson's favour. He could not very well erect an engine exactly like other folk's. He was certainly a practical engineer, and he was supposed to have taken the engine in hand to introduce something "new." The boiler was saddled with two eight-inch cylinders let into the top, and fixed vertically one on each end of the boiler. The application of two cylinders had already found favour with Blenkinsop and Hedley; in fact, Stephenson's first engine combined a little of both. The principle of the boiler was Blenkinsop's, and the motion Hedley's. Blenkinsop was the first to use two cylinders, and Hedley was the first to use spur-gear and smooth wheels. But smooth wheels without spur-gear was not as yet introduced; but engineers were getting nearer and nearer to such a contrivance, and it was George Stephenson that first accomplished it, as we shall show presently. In his first engine no doubt he used spur-gear, as Blenkinsop and Hedley had done before him; but neither Hedley nor Stephenson used the rack.

It is a most singular thing that none of them thought of making an engine with a horizontal cylinder like Trevethick's first engine. They could remember his spur-gear for communicating the motive-power to the

wheels supporting the machine, but "none the bit" could any one of them at that time think of copying the principle of the engine in its entirety.

The pressure of the steam upon the piston was conveyed by means of the connecting-rod and small cranks to spur-wheels, in Stephenson's engine, all placed inside the framing. These pinions produced a great noise, and as the engines had no springs, there were considerable jerks at some parts of the stroke. Many a man has been ruptured by the engine riding roughly. When this engine, or in fact any other engine of the period, was working, one could not hear one's own voice for the rattle and noise produced by the motion.

An exact idea of what the noise was like may be obtained by watching an approaching traction-engine. The engines at Wylam and Killingworth with spur-gear, made just as much noise as a traction-engine. When, in the course of a revolution, the leverage of one crank became greater than that of the other, the latter was propelled by the former through the intervening wheels; but when the former approached towards the extremity of the stroke, its leverage became less and less, and the leverage of the latter became greater as the angle between the connecting-rod and the crank increased, and at a certain point the latter preponderated. When a change in the action thus took place, the former was then the propelled, and the latter the propelling agency. If any free spaces existed between the teeth of the cog-wheels, the transition of this acting force from one side of the teeth to the other naturally caused frequent concussions between the teeth, and caused the engine to lurch. This disturbing

action became greater as the teeth became more worn and the space between them greater.

We have observed that all this spur-gearing, with its deficiencies mentioned above, and experienced in the Wylam engine, was introduced to obviate the assumed difficulty, that the friction of the wheels of an engine upon the rails was not sufficient to enable it to move satisfactorily.

We observe, too, that to a great extent Stephenson's first engine was a mere embodiment of all the good points that he could find in other engines, and formed nothing extraordinarily new at this time. But he was on the way towards something that had not previously been properly appreciated.

The engine was turned out of the Killingworth shop on July 25th, 1814, and put to work on the same day, with no flattering results. In fact, Stephenson was "chapfallen;" the engine did not work better than others he had seen; in fact, it had much to do to crawl along, notwithstanding that it was a "Stephenson." He had made great exertions, but the engine possessed none of the advantages that the engine-wright had predicted; and the "Grand Allies" were not a little dissatisfied at the result of their twelve-months' work. The cost was as nearly as possible the same as the cost would have been had they employed horses. The engine would not ascend the slight incline, until after it had received alterations. The speed was four miles an hour, and the engine could only replace two horses. The engine was short of one thing, which is of great value on a railway, namely, Steam. Shortness of steam was its failing, owing to the amount of heating surface being comparatively small.

But this was only a portion of the evil; the extremely rude and inefficient mode of managing the fire and the heated products of combustion after they had passed from the furnace, was the greatest evil. Stephenson had no return-tube, as Hedley had in the Wylam engines; he had chosen the plan of boiler in use by Blenkinsop.

The fuel was imperfectly consumed, and the result was very meagre.

It was a great failure, and Stephenson as well as the "Grand Allies" knew it; and it was a critical juncture for all.

Why have meddled with the engine at all? Why not have consulted Hedley at first? He was at the neighbouring colliery with his engine; and to add to the vexation, Hedley's engines were going well; they were at all events more powerful, and they gave no such trouble as this "Blucher" did.

The failure of the engine was eating like a canker into the heart of the builder; and, to add to the unpleasantness, the machine was regarded as an usurper.

To wonder that the people jeered as they did, is much like wondering that the panther retains its spots, and the Ethiopian the blackness of his skin.

There were weak points somewhere. Could he cure them? thought Stephenson.

Build a new boiler? by no means. The "Grand Allies," like Trevethick, had had very nearly enough of it.

He could do what he liked; but make no more expenses.

What a contrast with the dreams that had soothed many a time the ambition of the engine-wright! His

engine "on stilts," the world ready for all sorts of mischief; it was trying indeed to any soul.

But Stephenson was ingenious and masterly in device; he was fertile, with a head like a carpenter's shop. These qualities were needed, and it was these that he had; it was in them that his strength lay.

He had joined himself to the cause of the locomotive, and he would throw the spell of his influence upon it.

The faults and the merits of the engine passed in review before his mind; he struck right and left into the question. What were the salient points, and what were the damning defects. All was laid open to view, it was the hour to deliver himself.

"It is my firm conviction"—had he not stated it to the Grand Allies?—"that I can make a much better engine than the Wylam one, one that would draw more steadily, and would work more cheaply and effectively;" the recollection of which weighed on and oppressed his mind.

And, further, had he not said, in respect to the Coxlodge engine, that "he could make a better engine than that to go upon legs."

"This bubble world;
Whose colours in a moment break and fly."

The big-blown scheme had burst; and the locomotive which was to surpass all that had preceded it looked better on paper than on wheels.

So far he had not exhibited any appreciable engineering skill. He had built an engine, it is true, but it was a very unsuccessful engine. Now for the cause, and afterwards the remedy.

Stephenson—and he is not the only one who has made the same mistake—had made his chimney too

large. It was 20 inches in diameter against 12½ inches at Wylam. He had also allowed the exhaust-steam to escape into the open atmosphere with a hissing blast, which had been done away with at Wylam by exhausting the steam into a chamber.

Neither Hedley nor Stephenson was aware of the real value of the blast in the chimney, from the exhaust-steam.

If Mr. Hedley had such knowledge, why did he blow the exhaust-steam from the cylinder into an intermediate chamber? why not have blown it straight into the chimney? Why use a chamber?

If Stephenson had such knowledge, why blow the exhaust-steam direct into the open atmosphere? Why not use a chamber?

At this very time of which we are speaking, Trevethick took out a patent for introducing fanners into his chimneys. None of them knew of the action of the blast in the chimney.

The cause of the failure of Stephenson's first engine arose from two things—too large a chimney, and no blast in it.

CHAPTER VIII.

THE BLAST IN THE CHIMNEY AND THE COUPLING-RODS.

WE now touch the remedy that increased the power of his engine, and which eventually established his fame.

Complaints had been made to the "Grand Allies" of their engines making a noise to the terror of horses and cattle, and the engine had been called a nuisance. To avoid this Stephenson had not done as Hedley had done—provided a chamber on the front end of the boiler.

In this dilemma, he had either to place a chamber on the boiler to receive the exhaust-steam discharged into it, or to carry the steam direct into the chimney. The result was that, in choosing the second course, he found the *full* value of exhausting into the chimney, of which Hedley had only realised a portion.

Stephenson knew that Hedley had, at least in part, realised the value of an exhaust into the chimney, for he did not take out any patent for the application; neither had Hedley done so; and the blast in the chimney remains to this day a great power, discovered by a series of accidents. It did not proceed from one man's brain.

Well, Stephenson was the first engineer to deliver the exhaust *directly* into the chimney: not by choice —or he would have patented it—but by necessity.

Hedley paved the way for Stephenson at first: it was he who introduced the locomotive near to Killingworth, when Stephenson could walk round it and could form an opinion of its capabilities if fully developed.

It was Hedley who introduced smooth wheels with spur-gear, and exhausted *indirectly* into the chimney.

One man labours, and another enters into his labours.

As might have been expected—now, but not then— the Killingworth engine was improved when the blast-pipe was led into the chimney. It, in fact, made it a successful engine. Combustion was stimulated by the blast; and, consequently, the capability of the boiler to generate steam was greatly increased, and the effective power of the engine augmented in precisely the same proportion without adding to its weight.

The blast in the chimney led Stephenson on to fortune. Hedley's blast was intense; Stephenson's was more intense; and, like all things else on the wheel-of-fortune, it needs but little, and but little time, to throw one engineer "off" and another "on."

It has been made a point to wade through the evidence respecting improvements, so as if possible to give honour to whom honour is due; but we come now to a question that presents itself, and before leaving this part of the subject, we must not forget the genius and industry of those men who, in season and out of season, materially advanced beyond all doubt the wealth and power of the kingdom.

Our greatest men are our engineers; and Murdoch, Trevethick, Blenkinsop, Chapman, and Hedley were labourers in the cause of locomotion. Their names will in time be written on one of the grandest monuments that the people of this nation ever beheld.

With the great resources of Stephenson's mind, he

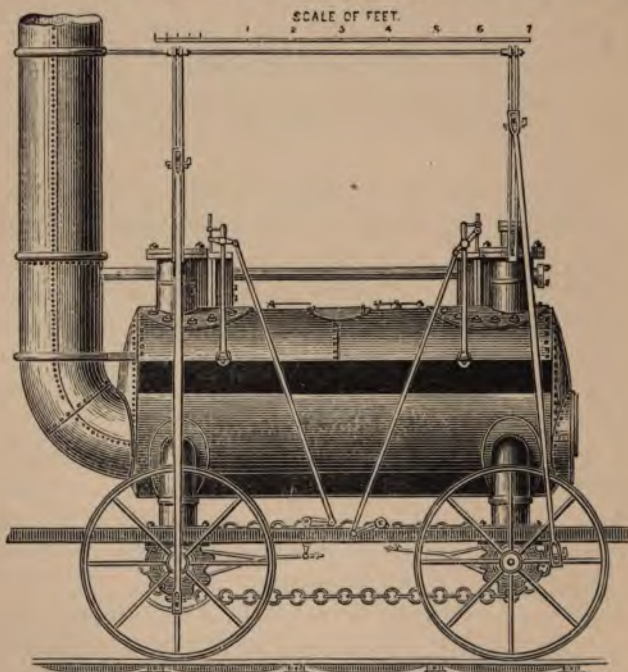


Fig. 10.—George Stephenson's Second Engine.

had achieved a victory; and there was nothing to do now but to follow the bent of his own genius. He built another locomotive, and instead of using spur-wheels, he adopted a chain and other improvements. The

specification is dated February 28, 1815. It was proposed to connect each of the connecting-rod ends to a pin upon one of the spokes of the running-wheels of the engine. On this system, the reciprocating motion of the piston and connecting-rod was converted by the crank-pin in the wheel into a rotatory motion, and the continuity of this motion was secured by one pin being placed on a radius at right-angles to the radius of the other.

Here we have a grand idea in itself. But instead of proposing to set the engine to work just as it is described, the specification goes on to state, "It is proposed to use a peculiar sort of endless chain passing over a toothed wheel on each axle." (Fig. 10.)

This was a decided step of improvement. The same principle of connecting the cranks at right-angles is used now. It was the first engine worked by connecting-rods by means of crank-pins in the wheels.

The chain contrivance underneath the engine was set aside for a better and more enduring plan. The two axles that supported the engine were cranked, and a wrought-iron coupling-rod was fastened to them; by this means the crank-pins in the wheels were maintained at right-angles.

The next improvement proposed was to do away with the jerking of the engine. Desirous to avoid the use of steel bearing-springs, Stephenson employed steam-cylinders with floating pistons for the support of the engine; two on each side of the engine, the end of the piston-rod acting as a thrust-pin on the brasses in the axle-box.

The inventor states that these pistons were capable of receiving shocks and disposing of their effects with

more certainty than could be obtained by employing the finest springs of steel to support the engine.

But these steam-cylinders below the boiler were found very defective; for, in the ascending stroke of the working piston of the engine, they were forced inwards by the connecting-rod pulling at the wheel in turning it round; and, in the descending stroke, the same pistons were forced as much outwards. This vertical movement in the steam-cylinder springs rendered it necessary to increase the length of the engine-cylinder as much as there was play in these steam-cylinder springs, to avoid knocking the end out of the working cylinders. This patent was taken out in 1816.

In the same year Stephenson, in conjunction with Losh, took out a patent for a railway wheel worth noticing. The boss was of cast-iron, with wrought-iron arms; the rim had lugs cast on its inside with mortise-holes dovetailed to take the dovetailed ends of the arms, which, after having been heated and expanded, were dropped into the holes in the rim. The arms contracting as they cooled, the rim was drawn inwards by them with great force, for the purpose of preventing its working loose.

In 1817, the railways, or rather tramways, about the north were becoming day by day more popular, not on account of the locomotive, but in point of economy as between the cost of carting and the cost of "tipping" coals from trams into the ships.

There were few people with money who had not speculated in railways. Amongst others in the north was Mr. Pease, of Darlington, a Quaker; and Quakers are generally in the swim of safe investments.

Locomotive engines were not thought of at this time,

lthough Stephenson had made them for the "Grand es," they were rather "shaky" things: there was a shadowy margin between them and horses. They not extolled as a wonderfully-paying machine, their fame was nil.

CHAPTER IX.

GEORGE STEPHENSON A RAILWAY CONSTRUCTOR.

In 1818, the Hetton Colliery Company proposed to make a railway, and to employ locomotives upon it; and they thought it would be to their advantage to obtain the services of George Stephenson.

They made him an offer and he accepted it: to lay out the road and work it with engines. He made every effort here to succeed with his engines; but when the Newcastle and Carlisle railway was projected, the directors, after witnessing what the engines could do, determined that no locomotive engine should be used on it.

They could see no advantage in locomotives, for fixed engines were in some places employed to help them up the banks by means of ropes coiled round drums; and, had there been any advantage, we may be sure that persons residing in the district would have noted it, and the fame of the engines would have been a topic of discussion.

Nevertheless, Stephenson made five locomotives at Hetton, with single-tube boilers. After Hedley's engine (which is in the South Kensington Museum), constructed with a return flue, these engines of Stephenson were looked upon as being defective; and

without doubt they were so in the opinion of many, but Stephenson did not think so. He held to them through good and evil report, which no doubt contributed to his final success, and to that of the engine. Very soon after he had made the Hetton railway as perfect as he knew how to make it with locomotive and fixed engines, he was informed that Mr. Pease, a promoter of the Stockton and Darlington tramway, had great influence in the promotion of railways. He procured an interview with Mr. Pease, and although this gentleman was in favour of tramways, he was not in favour of locomotives. This state of opinion shows that little or no progress had been made with the locomotive in 1821. Stephenson, however, said to Mr. Pease, "Come over to my place, and see them working yourself." Mr. Pease did so, and the impression was favourable. Even then, there was no final decision as to locomotives being employed, but as Stephenson had made the tramway for the Hetton Company, he could of course make one for the Darlington Company. Every one could see he was capable of making a tramway; and as to locomotives and their economy, of course the books of the "Grand Allies" could show whether it paid to use them.

The interview between Pease and Stephenson resulted in the latter being appointed engineer to the Stockton and Darlington tramway; and Pease made it to his advantage to move from Hetton to Darlington. After settling down, he was able to bring his engines prominently before the proprietors of the tramway, as they were employed in forming and ballasting it; and an Act of Parliament was obtained for power to use locomotives on the line for goods traffic.

Directly after this act was passed, Stephenson and

Pease opened a factory at Newcastle-on-Tyne, in 1824, for the manufacture of locomotive engines.

They at once made three locomotives for the line after the pattern of No. 1, with the motion on the top, coupled outside, instead of inside, by crank-axles.

It is interesting here to note that whilst Hedley abandoned cog driving-wheels and introduced the exhaust-steam indirectly into the chimney, Stephenson introduced the exhaust-steam directly into the chimney, and abandoned cog-wheels *altogether*; at first using a chain, then an inside connecting-rod with a direct motion to the pin in the driving-wheel; then he employed straight axles and brought the coupling-rod outside, as in No. 1. Yet we have still an uncomely arrangement: and that is, the engine or motion on the top of the boiler.

This leads us to the year 1825, ten years after Stephenson joined the cause of the locomotive.

When the line was opened, a coach was run on it; the fare was a shilling, distance twelve miles; time occupied, two hours. A locomotive to draw it? No; a horse. The fare was then the parliamentary charge of one penny a mile; luggage, 14 lbs. per passenger; the light at night was a penny "dip." This is a strange narrative; there are people now living (1879) who witnessed it.

The importance of this railway came gradually into view. There were, at the beginning, several coaches on the line, drawn by horses; and it was some time later when an engine was allowed to draw a passenger-train.

Coal-waggons were drawn by locomotives. There were no signals, and a "devil" full of coals was the tail-light.

Railways were coming more and more into vogue.

In fact, for several years, a number of merchants and gentlemen in Liverpool had mooted a project for making a tram-road between that port and Manchester, as Brindley's boats were unable to deliver the goods without much inconvenience to them and others. Little by little, the locomotive era was coming. Grocers, drapers, and shoemakers argued that the then state of things could not go on. The merchants resolved to go and look at Stephenson's engines in the north, and witness their performance with coal trains, and report. But nothing was done.

And the canal continued to be worked, but with no better results.

Then a surveyor was employed to fix the direction of the line, and he was also sent to the north to see the locomotives working on the railway there.

He returned with a very favourable report on their performance, and declared that they were the proper thing for Liverpool.

The fame of the locomotive was spreading, and so was Stephenson's name. Can't we look here and see how much fickleness there is in fortune? Look back and see the "great" Trevethick, and the "indefatigable" Hedley; where are they?

CHAPTER X.

THE LIVERPOOL AND MANCHESTER RAILWAY, AND COMPETITION OF LOCOMOTIVES.

HARDLY a day passed but some one hailed Stephenson from afar to make inquiries "if they paid," and on one of these occasions he was invited to "visit" Liverpool, and look over the intended road between that port and Manchester, and this happened when he had nearly finished the Darlington railway. He accepted the invitation and saw the road, and returned with several of the promoters of the proposed line with him.

He ran them on one of his engines, which attained a speed of nine miles an hour; afterwards they returned to Liverpool, and their report was so impressive that the shares of the Canal Company dropped alarmingly.

Every possible objection was raised by the boat proprietors and "horsey" people, for they thought the price of horseflesh would be the price of dog's-meat if locomotive engines came nearer to Liverpool. Locomotives would never do—never. And it was not alone these people who opposed the engine; the civil engineers also opposed it. Many of them said that the Liverpool and Manchester line would be worked more cheaply and better by horses than by locomotive engines, whose boilers would be always bursting.

In fact, it was looked on by them as a ridiculous idea.

However, it was regarded by a select number of merchants as a paying project, and they resolved to introduce a bill in Parliament for permission to make a railway.

Counsel was employed for and against it. On March 25, 1825, Stephenson was examined, and, as might have been expected, many ugly questions were put to him. He was "plucked."

He was a thorough practical man; but dodge counsel round a point, and perhaps a nice point, he could not.

We have all heard of some of those questions put to him; they are very good. One was: "Suppose you were going ten miles an hour and a cow was on the line, what would happen, would it not be very awkward?" The reply was, "It would be awkward for the coo." Another question was: "Are not your red-hot chimney ends likely to frighten people?" Answer. "How are people to know if the chimney-end is not painted?"

Finally. He had made in his time sixteen locomotive engines; and he retired with this announcement from his tormentors. Result: the bill was rejected.

Stephenson goes to Darlington, and the railway promoters to Liverpool to concert what should next be done.

The promoters called in another surveyor, obtained another class of witnesses, and presented another bill to Parliament—with success.

Even then it could not be decided what was to work the line—horses or engines. They called in a professional engineer, paid his expenses to Darlington to see

the locomotives working there, and on his return he actually decided in favour of stationary engines.

There was, however, a division of opinion with the committee, and it ended in deciding to appoint George Stephenson engineer.

He accepted the appointment and made the line, employing one of his locomotives at the work. It was an appropriate thing to do, for as the engine moved about the line, the directors had an opportunity of forming a correct opinion of its merits.

Of all the railways that had hitherto been constructed none could compare with the Liverpool and Manchester.

It was the most perfect piece of road ever constructed, and great national interests were involved in it.

It must suffice here to state that George Stephenson made it, and a thorough good mechanical work it was. In its construction about 4,000,000 tons of stone, clay, and soil were moved; the total expenditure amounted to £820,000.

The length of the railway was thirty-one miles. It was laid with eighteen miles of stone-block sleepers, and thirteen miles of larch sleepers.

After mature consideration of what the directors had seen, of what had been reported and calculated by various engineers, it was decided in April, 1829, to have a trial of locomotives, and then determine on the best description of power for the line.

Fixed engines at this time were much preferred, and the conditions and stipulations of the locomotive were such that many people thought that no man could comply with them. Such were the disadvantages imposed

by self-interest, and there was much self-seeking in respect to this line.

The stipulations for the engine were :—

1. Improved construction.
2. Best locomotive.
3. Boiler to stand a pressure of 150 lbs.
4. Boiler to work daily at 50 lbs.
5. To consume its own smoke.
6. To draw three times its own weight at ten miles an hour.
7. To be supported on springs.
8. To have two safety-valves.
9. Height from rail to chimney-top 15 feet.
10. If less than $4\frac{1}{2}$ tons in weight, to have four wheels under it.
11. If over $4\frac{1}{2}$ tons, to have six wheels.
12. Not to exceed 6 tons in weight.
13. Not to cost more than £550.
14. The approved engine to receive the prize of £500.

An engine that should comply with these conditions must have been a most important engine. There was nothing like such an engine in existence ; but the result would be, if achieved, a great stroke of luck. The engine and its builder would be the chief of their kinds, and the success would, besides, add to other benefits.

The manufacture of a locomotive at this time required a considerable amount of skill; it was a special calling. It belonged to few firms, for it cost much in time and money, and besides, the locomotive had but few friends ; hence this trial. On the Stockton and Darlington railway, the engines worked for a long time very indifferently.

And why? Because the heating surface was small, and the waste of fuel was great; and the construction exhibited an almost incredible want of ingenuity. The owners expected work done, and the engines did none, comparatively speaking.

The factory at Newcastle was a "well," for the money went and did not return. This was not according to Pease's policy of life, and he wanted to get out of it. But George Stephenson had not sufficient gold to pay him out.

The locomotive at this very period was generally in great disrepute.

In many ways it had improved, but after all it was a costly article.

A good deal of all this was caused by Stephenson himself—not availing himself of the best boiler *at first.* In 1828, he employed a return-flue boiler, as Hedley had done in 1815. Here we have twelve years in which the best boiler was disregarded. The complaint was always that there was a want of steam.

It was an enormous sacrifice on the part of Stephenson to ignore Hedley's boiler for so extended a period.

Now, the peril involved in this proposed trial could not have been better appreciated by any one than by Stephenson, and therefore he permitted nothing to escape that would increase the *heating surface.* He was not only willing to copy, but to listen to any practical suggestion, and, by doing so, he planned the Rocket engine with horizontal flue-tubes. This was an idea given to Stephenson by Mr. Booth, the treasurer of the line. It was not a new idea, and no doubt Mr. Booth had seen it applied in steam-coaches. However, the idea came very opportunely, and brought all the success

which afterwards fell to Stephenson's lot. It is a grand lesson, and it shows that greatness of character and fame do not always depend upon one's self.

He is great who does greatly in things of every-day life, and follows up the line of duty sincerely, and with a sense of humiliation, calling every man brother, leaving the marks of a bright and genial soul.

In the surmounting of difficulties in erecting the

Fig. 11.—The "Rocket" Prize Locomotive Engine.

Rocket, there was a marked improvement; tokens of progress everywhere. Stephenson had passed at a bound to a tremendous success.

On the day appointed for the trial, the following engines were entered at Rainhill:—

The Rocket.
The Novelty.
The Sans Pareil.
The Perseverance.

The Rocket (Figs. 11 and 13) was distinctly different from the other engines, in having twenty-five copper tubes 3 inches in diameter, and a fire-box riveted to the end of the barrel, surrounded with water, much after the present style. The water-space at the sides of the fire-box was 3 inches wide. The cylinders, 8 inches in diameter, with 16½ inches of stroke, one on each side, were bolted to the barrel of the boiler at an angle, and the piston-rod and connecting-rods worked outside. The latter were coupled to crank-pins in the leading-wheels, which were 4 feet 8½ inches in diameter. The trailing-wheels were 3 feet in diameter. The exhaust-pipe was outside the boiler, and was carried along the side into the chimney, producing a good draught.

WEIGHT.

	To.	cwt.	qr.	lb.
Engine . . .	4	5	0	0
Tender loaded . .	3	4	0	0
Total . . .	7	9	0	0

HEATING SURFACE.

Fire-box	20	square feet.
Tubes	117	"
Total . . .	139	"

PRESSURE.

50 lbs. per square inch.

For several days, the engines made preliminary trials, before the contest came off.

The next engine to notice is the Sans Pareil (now in the South Kensington Museum), made by Mr. Timothy Hackworth. It was an attempt at something better than had hitherto been done, and, further, it represented the talent at Wylam at this advanced period.

George Stephenson's engine, Rocket, was a single-

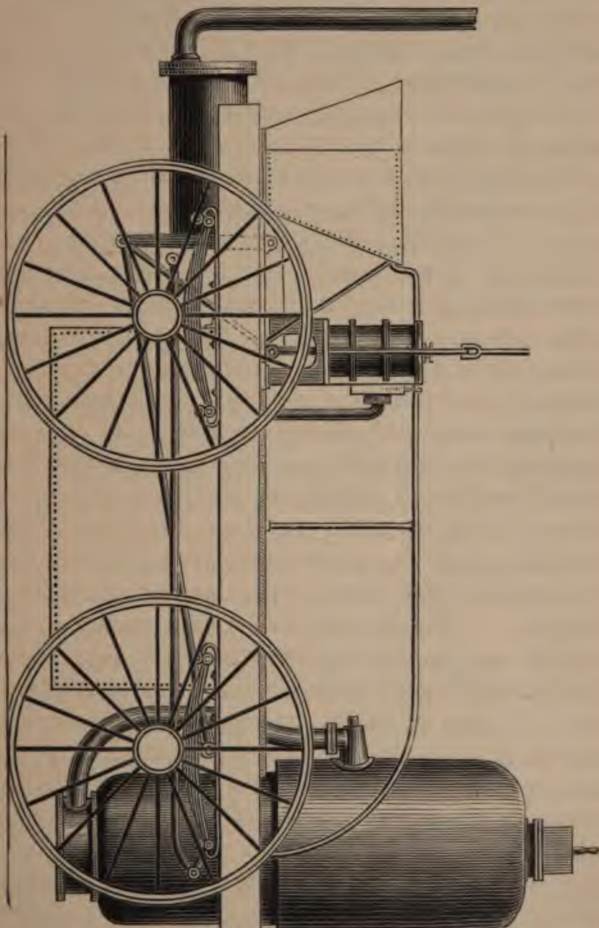


Fig. 12.—The "Novelty," by Braithwaite and Erricson.

wheel engine, the first that was ever made, and Mr.

Hackworth's was a four-wheels coupled engine. The cylinders were placed in a vertical position, and the boiler was cylindrical with a return-flue, the chimney and the fire-door being at the same end of the boiler. This kind of boiler was known as the Trevethick boiler.

The fire-bars were inside the tube, as in a Cornish or stationary boiler. The piston-rods were connected by the connecting-rods to crank-pins in the hind-wheels, which were coupled to the fore-wheels by coupling-rods. It was a very simple and compact engine.

But, of all the engines that were entered for the trial, none was so popular as the Novelty. There was more workmanship about it than about any of the others, and it had the appearance of being an ingenious construction. It was made by Messrs. Braithwaite and Erricson. The day for the trial arrived, and it was made the occasion for a holiday by everybody about Rainhill. A "grand stand" was erected, and a charge of five shillings was made to have the privilege of witnessing the "horses" go from one of its seats. Shooting-galleries and all the fun of the fair were collected. Jokes passed pretty freely between boatmen and stage-coachmen; both had a stake in the race, and a heavy stake too. The boatman could not see how his canal could be shut up by an engine, for had not God made the rivers to feed Brindley's canals? and there was no answer to such a clenching argument. The coachman was so much in love with his coach and horses that he was stone-blind. Did not He who made the lion to roar, make horses to draw carts and carriages? and what is the coach but a carriage? With an extra crack of his whip, he felt as safe as the bank.

It was a splendid morning, and the iron horses,

looked upon as huge creatures, were saluting the people with sonorous puffs from their iron nostrils, working to and fro in their harness.

Country people took a look at them, and each had his "clipper," and a little bet on. The spectators, one and all, as the time drew near for action, were excited beyond measure. The moments were alike fraught with lively interest to the locomotive engineers. The project had cost them many an anxious moment.

They, each according to his ability, had shown active interest in the matter.

All had a desire to lead against stationary engines. But each engineer that "showed" an engine coveted the prize; and not the prize only, for the merit that would be attached to it would be the making of a fortune. The capabilities of a locomotive engine were going to be most forcibly tested, and the popular points were strangely and absurdly jumbled together by the great concourse of spectators.

But, here is the Rocket before the judges. She is weighed, and found to conform to all the stipulations of the directors, and is placed on the trial length, which was marked out by two posts, 1½ miles apart, and she ran ten trips to and fro between the posts. The average speed was 14 miles an hour. The last trip was accomplished in 3′ 44″, or at the rate of 24 miles an hour. But just on her coming up on her return to the starting-post, about to have achieved the grandest victory in the world for speed, the Rocket struck Mr. Huskisson, who was Member of Parliament for Liverpool, and who was standing foul of the road, and knocked him to the ground in front of the engine and run over him. He exclaimed to those who picked him

up, "I am killed." He was conveyed to Liverpool at the rate of 29 miles an hour, and died there.

The next performance was that of the Sans Pareil. On coming to the starting-post to be weighed, as the Rocket had been, this engine was found *wanting*. It is very difficult to understand how the deficiency could have happened. There were the conditions to be read and followed by all, and yet by not studying them and endeavouring to conform to them, this engine, the judges declared, could not strictly compete for the prize. The damaging feature in the engine was that it was supported only on four wheels, weighing $4\frac{3}{4}$ tons instead of $4\frac{1}{2}$ tons; therefore it should have stood on six wheels. Its weight might then have reached 6 tons and still it might have been admitted to compete. This was a very great oversight, and must have been a source of great annoyance to the builder.

However, the Sans Pareil was allowed to run, to show what it could do; and, no doubt, also to see whether by its extra weight it had any tendency to put the road out of order.

The first seven trips were performed very nearly as satisfactorily as those run by the Rocket; but, in getting through the eighth trip, the pump failed, and for want of proper precaution the lead safety-plug was dropped, and this accident closed the performance of the engine. The blast-pipe in this engine was not properly proportioned, and as there was no smoke-box, the red-hot, half-burned coke was carried away up the chimney. There was great waste of fuel, of which the consumption was three times as much as that of the Rocket. Compared with the Rocket, it was an inferior engine in many respects, and it would not

have made a very good impression in the absence of the Rocket.

The Novelty was the next machine to receive attention. It was quite a differently designed engine from either of the others. It broke down by the feed-pipe bursting, and Mr. Erricson would not proceed to trial.

Fig. 13.—The "Rocket" at work.

CHAPTER XI.

GEORGE STEPHENSON, THE SUCCESSFUL.

George Stephenson had won—won all—won everything; and the fearless consistency with which he had acted made him the foremost locomotive engineer. Having once fixed his mind on the cause of the locomotive, he stuck to it with a devotion which has never been equalled.

He regarded it as the sacred business of his life, and now the dreams and cherished hopes of years stood ready to be realised.

After he took the locomotive engine in hand, nothing escaped him that could raise it; all the changes he made to-day removed some deficiency of the engine of yesterday. Hardly was one new idea reduced to fact, when another idea came to the front. From obscurity, he welcomed everything that would add to his reputation; and this working, unflinching perseverance drew him towards the one ultimate achievement, when he stands before us as a model—the author of his own advancement. He teaches us in a practical form that, under certain conditions, success is certain. He teaches us that the path in which our natural power is great is the right one. He teaches us that to speak with our own voice, to stand for our own work, and stamp it

with our own originality, is to follow close up to a triumph, sooner or later.

Every line in his life—page after page, and chapter after chapter—shows that, however humble our origin may be, our life, like his, is capable of indefinite growth.

His life was for a long time passed behind the scenes, and at times under a cloud. Remember how he wept because he had not six pounds with which to discharge the soldiering liability. The merciless severity of the conviction that he was uneducated, drove him again and again to the task of cultivating what nature had given him as his dowry—heart and brain. He found himself in a mist, and found his way out himself, for he had resolution, ardour, and courage, either to do battle or seek to reclaim whole acres of intellectual worth. Again and again he would invade his bewildered understanding in the meaningless altercation that went on within himself, in the sphere he was daily creating. Where was all this leading to? To the light. The conflict within was the unskilled utterance of the hopes and dreams of a young, ardent soul yearning after truth. He would, at times, be quite uncertain of his own aim; and all he could tell was that the more he knew, the less he found to talk about, and that his gains intellectually would be utterly disproportionate to his labour. But it is always so; it is really characteristic of solid advancement: the intellect slowly paces down the dark gallery that leads to the chamber of light. The new birth of the mind is accompanied by pain ere it can join the sons of light and knowledge. Have we never heard that the claim to knowledge without the prostration of soul was fatal to intellectual strength? It is. Until this ordeal is

passed the mind is unstable, it wanders, and it cannot be fixed on any particular question; it has not muscle enough to wield the sharp, dividing axe of argument, nor strength sufficient to receive a heavy blow in the battle for truth. Perils and honours in the realms of mind are elaborately wrought together, and there is no dividing them. Any one who will take the trouble to read the "Life of Stephenson," by Mr. Smiles, will find there much to refresh his strength in the struggle to improve himself. He will see that Stephenson had his dark hours and his gracious moments, his rivals and downfalls, but by absolute sincerity of purpose he became the prince of his art—Stephenson the immortal.

Having reached his climax, he felt he was safe, in the right, and his enemies in the wrong. With a fascinating charm, after the victory at Rainhill the railway interest was always before him. Step by step, line *on* line, line *upon* line, here a line and there a line, improvements followed each other so rapidly that all further effort to establish the locomotive was completely ended. "'Twas a glorious victory," and all the art and skill that can possibly be summoned cannot *direct* how to find out what the consequences would have been if it had been lost; all conceivable conjectures teach nothing. It is well with us as it is, for it conferred upon the nation a fresh charm, imperfectly understood at the moment, for the nation never had such a gift before like it. But, as years roll on, the world is gradually giving its mind to regard it, for its colossal value, for its attractions, interesting the minds of all.

PART III.

CERTIFICATES OF QUALIFICATIONS IN THE RUNNING SERVICE, LOCOMOTIVE DEPARTMENT.

CHAPTER I.

THE MANAGEMENT OF A RAILWAY.

THE service now performed by our locomotive engines is splendidly done. The service that could be performed in case of invasion is momentously important. The ease with which it could be done without risk is evidence of practical ability of the highest order. Ten locomotive engineers with their engines could transport ten thousand soldiers, trained ready for the field, to a distance, and in so short a time as was never dreamed of until Stephenson, by his desperate tenacity, reason, and rectitude, made it plain and proved that it was practicable to hurry through the air, and contemptuously disregard cold, wind, darkness, and everything else. The railway has grown; and with its growth there has followed employment for hundreds and thousands.

The colossal business of railways is divided into sections or departments, and the General Manager is at the head of all.

He is a man with fine administrative ability, quick as lightning to distinguish pretence from real worth, and to see through character. He is like an officer in command of a great army; and, unless he is full of expedients for the destinies of all under him to come in review before him, there will be much dissatisfaction in the ranks. He is a man acquainted with human nature, and the service requires this insight more than anything else. The fussy, blatant fellow comprehends how soon his house of cards will fall in presence of the General Manager. The self-asserting become distrustful, though they are always on the look-out to catch his eye. The babbling fellow is afraid lest some one else will supersede him in the General Manager's opinion; and, to convince him and the world of his value, he puts on cheap ornaments and stucco decorations, and is as tawdry inside as outside. Cut him up, and he will be found full of dead men's bones. What a smart fellow! Silly fool! we know you to be boastful, quarrelsome, elbowing your way, and putting a value on yourself that never was and never will be yours. Such an one the sagacious General Manager plucks.

There is nothing like seeming what you are. You will lose by it *for a time;* but unflinching fidelity, never condescending to a trick, will make you lovable and loved. Have no false creed with a painted roof over it. Stand on truth, with the sky visible, and no one between you and the sun. Such an one the General Manager looks on with honourable regard.

In the locomotive department, the chief is the Locomotive Superintendent, who ranks as one of the highest officers in the railway service. His position requires

that he should have received a thorough mechanical education, trained at the vice, and by experience. He is an engineer in every sense of the word, loving nothing better than engines, and able to hold his own on any locomotive question; and those under him with like talents receive their just reward. When it is otherwise, talent starves and mediocrity thrives, and a fatal chill penetrates the better material. To co-operate with accomplished ability, and to hold the wand of his influence over all, is his aim.

The chief engineer of a locomotive department may be said to have two spheres, namely, the work of the erecting-shop, and the business of visiting the depôts outside. In the former vocation he builds engines, in the latter he hears how they answer. It is a simple arrangement, but it demands efficient talent.

He stands in the midst of ceaseless change, but he himself is unchangeable, mild and reticent, having mastered all the possible changes that can occur to the engine, or in the steam-shed.

In this should consist his superiority, and it should bring with it every possible obedience to his decisions. When it is not so, subordinate officials concoct plans to upset and even ruin, if possible, another official. He should be a Ulysses with his ears stopped, with a knowledge of the encyclopædia of the locomotive and of locomotive-working, so as to stamp out wild and quack panaceas, that can do no good at the best, and can only upset his men, and breed disgust and contempt, which is like dead fruit in the mouth. The scope and object of this department is mainly to work the traffic, and that being so, the great problem is to institute systematic accounts, to ascertain the minimum economy and the

maximum extravagance in the performance of the work; and to strike a medium course—neither the minimum nor the maximum is safe. Discrimination is required to be exercised as a check or safeguard to maintain an efficient service.

The first step to be taken for practicable results, consists in the appointment of efficient foremen, well-selected, carefully drilled by force of experience and circumstances, understanding thoroughly the action of the natural laws of nature, detecting a deviation from right, and unravelling the mysteries of wrong.

CHAPTER II.

THE LOCOMOTIVE FOREMAN.

The position of locomotive foreman needs the strength of experience. It requires and is generally held by men whose minds have been thoroughly annealed by the elaborate influence of cause and effect, found to pervade all locomotive working. He is as much at home under steam with a train at sixty miles an hour, as he is under the office roof. He is able to investigate the cause of engine failures, can pick an engine up or cure a choked fire, and knows how side-winds and storms affect the steaming power of the boiler, and prevent the engineers from keeping time. He is a fully-developed fact, in keeping with the engines in his charge; hence his claim to lead. Who can command unless he has served? He gives full proof of his position, supplying those under him with keys to unlock any boxed-up locomotive question, since he has himself by his necessary pursuits qualified himself to do so. To him there is nothing mystical in the operation of locomotive working; he has discovered the *elixir vitæ* long ago, an universal solvent. He attains this high state of efficiency by making notes, by prohibiting all attempts to let fancies, prejudices, or local influence deter him from "letting himself," body and mind—in

fact, until all is plain. He has seen for himself and can speak as an authority.

A locomotive foreman should have served under the several forms or phases of locomotive life, having pursued a career and possessed gifts that fit him to lead locomotive engineers. It is possible for a man to have had a career of experience and yet not the gift of command. It is possible to have a gift and not the career. The real source of influence, weight, and power required for a locomotive foreman, is sympathy. It is not merely as a driver, and he being a scholar, self-educated if you like: it is not merely he being able to discuss a popular scientific question, that a foreman will succeed or have an acknowledged claim amongst the men under him It is rather by sympathy, it is as a teacher, that he will exercise his influence and be honourably respected. This is an influence due not so much to any great superiority of intellect, or length of service, as to the kindly fellow-feeling which one man should have for another; to the outspoken experience that accords with what the brother has seen, felt, and heard on the way. But, if the foreman has no experience of similar past events within himself, he is an iceberg, and what thrives before an iceberg?

A captain returning home to the admiral reports:—"Admiral, I lost my ship's anchor entering the Bay of Naples." "Well, and what then?" "Why, I had to get another." "Get another? what do you mean?" "I mean," said the captain, "that the tide, time, and circumstances would not allow me to recover the old one."

Now if the admiral is a book of experience—himself a sailor—he knows at once how much of the captain's

mishap is due to accident and how much to negligence. But if he is no sailor, the dignity and elevation of his office is lost, his reply will bear the marks of a man who either pretends to know, or, not choosing to look so small, snubs.

The interest which really surrounds the foreman is the same that surrounds the schoolmaster; and where it is not so, sooner or later, there is sure to be trouble. A locomotive foreman's work requires plenty of energy, not so much for the work of general routine as to "plug up holes" that are daily made by wear and tear; and not so much of that as to find out how to reduce the number of holes every day. In one instance, engines were frequently late in leaving the yard, and therefore late at their trains, until it was made the duty of one man to see every engine away to its time, and book the time in a little pocket-book given for that purpose. Ever afterwards the nuisance ceased. It was said that the enginemen should get out of the yard, but it was proved that a block was caused by some men wanting to come in and others wanting to go out. All this inconvenience vanished by the introduction of a man who represented the foreman, whose responsibility did not cease until the engine was on the main line, or, at all events, clear of the shed points. Again, engines were late in getting up steam, because the foreman thought that he could put old heads on young shoulders, until experienced men who had been on the road, and reduced, were put to it. Such men having been drivers are the best of hands for the purpose of fire-lighting. Again, enginemen and firemen came late on duty for early trains, until a lad appointed to call them did not return from their residences without

receiving their number-tickets, which he brought as evidence of his having called and seen them. This put an end to that.

Engines were put away without coaling, the day coalmen and night coalmen shirking their duties, and shifting them from one to the other; but by paying them by the ton, they scrambled for coal tonnage.

Sometimes drivers were wasteful with coal until they were allowed so much per mile for each engine and each carriage; this mode of allowance made them frugal. If they could run with any less quantity of fuel per mile, they received a premium.

It was found that engines were frequently running the white metal out of the big-ends, on the first trip after washing-out the boiler. This was proved to be caused by the big-ends being below the level of the crank-axle instead of above it, and the lime in the water dripped and lodged between the cheeks of the crank and the brass. A cure was wrought by orders to see that both big-ends were above the level of the shaft, before washing out the boiler.

Everything that savours of a deviation from what is right working should receive full investigation, and the conclusion when found should be made a note of. There is nothing impossible, and all things in locomotive working are easily remedied if the foreman acts with common sense; because there is never one wrong without another wrong somewhere about, and both must be dealt with.

If the head of one is cut off it will only come again —hydra-headed: but unhead both, and the end is absolute.

In the yard, the impress of the foreman's mind should

be definitely stamped on all things; and not in the yard only, but in the stores and the time-office; on the shed floor, and shed walls; with the view of applying the example to the minds and hearts of the men, that they may repeat it on the engine: such sympathetic feeling for the men should be of a most energetic character, in looking after their requirements, and guiding them to the right, in all questions relating to their engines, and not leaving the men to find it out.

He should scout half-faith in all things—all things are possible.

Not wanting in the faculty of preventing others from making mistakes, trained upon the exactest observation and the acutest reasoning to regulate and work out men and engines to a right issue.

CHAPTER III.

THE ENGINE-BOY.

In a large school like the steam-shed, the atmosphere is a strong solution of books, but all that is learned here comes of hard-earned experience.

The first stage in the experience of the engine-boy is a very trying one. High and mighty resolves he may have made to reach, by dint of perseverance, the highest place in the steam-shed, which to him is no other, more nor yet higher, than that filled by an engineer. But the continuous and absorbing demands upon his youthful energies soon try his mettle, and he either breaks down, or, surviving the ordeal, trots on hoping against hope to get relieved of such fearful work. His portion in the hive is to get into hot fire-boxes, where the heat is sometimes 250 degrees; and he must not flinch, but accomplish with courage his new and difficult task—namely, to clean the fire-box of clinkers, and work the cinders off the brick-arch. He is furnished with a torch-lamp, a short rake, and a steel broom. He uses the broom to brush down the tube-plate and prick the tubes out. In practice, the fire-bars are not pulled up by the fire-dropper, but the remains of the fire left in the box, after the engine has arrived from her trip, are taken out of the fire-box by

means of a splice. When fire-bars are pulled up and dropped into the ash-pan, the treatment not only tends to warp and even to break them, but it damages the ash-pan to a very serious extent; and, when this barbarous plan is employed, the fire falling against the dampers not unfrequently renders it unfit for controlling the steam. Moreover—and as the best way to get over the work in a steam-shed is to have no work made at "home,"—the lifting of the bars places the engine-boy under the necessity of relaying them on the rack, or placing them on the supports fore and aft of the box. While he is doing this, he might have been cleaning and brushing many other boxes. The cry for the bar-boy, which is continually uttered, arises chiefly from his labours being rendered unnecessarily heavy by the absence of proper instructions issued to the engine-turner not to lift bars himself, and to correct others when they do so. It has occurred that in consequence of some bars not having been properly cleaned, the engine has been "shy" of steam, and has lost time with a train, for which the engineer is bound to account. But he is loath; being a man, he is disposed to blame the boy, but ventures to cure the difficulty by pulling up the whole lot, rendering it obligatory of the lad to replace them in the frame. This is one way of knowing that all the clinkers have been taken out, but it is a miserable way, and the practice should be discountenanced by all foremen.

The only and proper plan is to see that the bar-boy is placed *under* the orders of the fire-lighter; and neither of them should assume anything about it, but the foreman should see that they understand it. The fire-lighter should be held responsible for the cleansing

wheels are washed instead of wiped. When they are wiped—and that is the best way—he is allowed an oily "patch," and if he is up to his work he will get another, or even two oily patches off the motion. Even in the most economically managed engines, a small quantity of oil hangs about the motion. A good master makes good men, and a good foreman-cleaner is an invaluable agent, who in many instances moulds and forms many a lad's ways for life. First impressions never fade. If a lad does not meet with a foreman at first who is thoroughly qualified for his position and capable of teaching in more ways than one, it is a great misfortune to the lad and to the locomotive superintendent. All our cleaners, we may say, are ploughboys; and unless the right kind of influence is brought to bear upon them in the formation of their characters, at once on entering the steam-shed, ploughboys they will remain. There is plenty of proof that this is a fact, without our being required to write more in proof of it. But where are we to find a remedy? Not in drivers who have been reduced for drink, for insubordination, for want of respect for the property of the company, or for gross incapacity. Such an one put into office is a "mock pillar," a duffing attempt on the part of those who recommend it to pull a gorse bush through a chimney and not disturb the soot. Pitch defiles. Sometimes we see a cripple placed as a foreman-cleaner, and provided that he has been a very clean fireman, or driver, he may exercise the right sort of influence, but all cripples are not so qualified. The man who is set up to instruct should himself be a master, and the instructors in our steam-shed should have a master's ways and a master's command. All the ugly material travelling on the engine footplate at the

present time, that is too far gone to bend, is in many cases a chip off the old block. Very well. When the foreman-cleaner is a reduced man pushed into the job without any qualifications, he is always on the growl and wail. The calling, not having come from choice, is distasteful and unpopular. He has a bone to pick, depend upon it, with some one; and he will, mark it, call the cleaners round him to assist. His administration is a defective machine. Struggle there is none; he has collapsed. Dying from inanition; dead as a door-nail. Such are facts, not everywhere, not in every steam-shed; but still the evil above-mentioned exists. Again, when the foreman-cleaner is a reduced man, he enters the office with the conviction that he shall—like many another—be reinstated some day sooner or later. He knows it is only a case of "grin and bear it;" he considers that he did not take the berth, but that the berth took him. Why, it never entered into his head that he was appointed to receive young lads, speak kindly to them, and instruct them how to wipe an engine clean. If any one doubts this, he being an engineer, let him ask his cleaner when the foreman was under the engine last; and where his attendance has been slow, or has not existed at all, he will find the man not qualified to be an instructor again. When the foreman-cleaner is a reduced fireman, or driver, his wistful eyes always look in the direction of the lost "estate," and not at the dirt on the engine; and, what with intrigue and undermining, his hands are full without any waste in them; and during all this time the engines are accumulating dirt and wearing the motion out. When does such a foreman go under the engine and advise as to the best

way of *making a clean engine;* or for the purpose of showing a cleaner how to use his waste to the best advantage? Never. He may teach well-intentioned lads to grumble. Teach! he can only teach young beginners that the road to the lever is *not* found by energy, pluck, soul, and painstaking perseverance. He himself is a stone statue that sends a cold chill through them, and sends hundreds and hundreds away to the plough again. The intolerable atmosphere, and the treatment from such foremen, is at the least unpleasant. But many of these cleaners, after they have smelt a hot copper fire-box, go away to better themselves, very likely at a brewery; as what?—God spare the mark—an engineer.

Again, a foreman-cleaner with a leg off cannot very well climb in and out of the engine-pits, and therefore we have a "bad joint" at once; a foreman-cleaner with an arm off has a bad joint also, for the noble art of self-defence is not confined to the steam-shed. It has been called into requisition by the District Superintendent of the Northern Division of a branch. We have seen that a man labouring under the yoke of some painful visitation, whether incurred by incapacity or accident, is not and cannot be in a position to impart wholesome instruction to the rising engineers. Now for "true grit, the solid gneiss."

The foreman of the cleaners should have undertaken the office by choice, and should be qualified, by well-known habits of cleanliness, to warrant his being a pattern of order, and as clean as a pink. That there are men who have spent some time on the railway fit to fill such an office, no one will deny. Then why should it not be held by such men? There are drivers who,

on account of outside work being too trying to their constitution, are ready and glad to seek shelter inside. There are drivers whose "helpmeets" are always in fear lest the bread-winner should be "brought" home. Many a good woman has sat up until the hour is past for the "Mail" to be in, and then laid down in her clothes, waiting for what has turned out to be a messenger of bad tidings.

"The foreman," says the messenger, "has sent me over to tell you there has been a pitch in, and the mail is not in."

That is all, but it is enough; no further information comes. She does not know where it is, nor how it happened, nor who caused it. "Anybody killed?" asks the frantic woman. "Don't know," says the messenger; "heard, though, that both lines were blocked."

"If you hear any more of it, will you," asks the driver's wife, "come and let me know." The boy hears no more, because he is soon off duty, and the poor woman watches and watches until break of day.

The news comes that the driver is killed, and his fireman too. These sudden changes, made more awful by their suddenness, are common occurrences in the history of families depending for bread upon iron and speed.

Well, many a good man, from motives of kindness to his wife, is willing to take this office; men qualified in every conceivable way. Such an one, retired from the storms and other contingencies inseparably connected with the foot-plate, would traverse the shed with the cleaners full under his sway. With what delight, with what ecstasy they would clean under a man they were satisfied was neither a duffer nor an unfortunate

cripple, but a duly appointed instructor! On the ground that a good beginning makes a good ending, it is only logical to conclude that a bad beginning makes a bad ending. If this appointment had the consideration it deserves, the status of the engine-boys would be raised fifty per cent. in a very short time. We should have the best-wrought characters and bright-souled men. Look at the character of many of our steam-sheds now, especially at night-time; they are, in many instances, areas of blasphemy. Why do engineers, taking fifty shillings a week, refuse to enter their lads as engine-boys, and prefer sending them to trades at which they know perfectly well not near so much money can be taken every week?

Because they feel it would be sacrificing their children to Moloch, literally setting them in an atmosphere that would choke every good principle that had been instilled into them by good books and their mothers' prayers. Who are they then that fill our sheds at the present time, if the drivers refuse their sons? Why, in some cases it would be easy to prove that the cleaning-sheds are filled with the very scum of the earth, the lowest of the low, who cannot speak without an oath, who smell strong of stale tobacco before the sun is at the meridian. The figures that some years ago used to call on us are getting scarce. Not the high-souled lad who, touching his cap, says, "Please, sir, I would like to be a driver; I would like to work at anything until my body is as big as my heart is now, and my muscles are matured for handling a regulator. Please give me employment."

One impression and one only, in keeping with their dress and odour, do they convey, standing every morning

chiefly outside the shed-doors; and that is, the impression of the *cup* about the lips, eyes clouded and dull, and a voice like the screech of an owl. This is no exaggerated case. Ask all the locomotive foremen who have had bad foremen-cleaners if it is not correct. The picture seems forlorn and perhaps alarming to outsiders, but the experience of drivers clenches the fact. The atmosphere of the steam-shed requires cleansing quite as much as the Augean stables did; but where is the Hercules that will interfere, eager to effect a reform where reform is needed.

The rising engine-boys should be made to feel that they are cared for ; and who can tend them better than a man who has his soul in the work?

The rising engine-boys should be stimulated in their arduous work by an ambition for something better. The drudgery of a cold night in a shed, when almost everybody is warm between blankets, should be counterbalanced by some substantial foretaste of the better future. How many hundreds of brave lads leave their homes and their charms every night; and, animated by a high ideal, spend it in a cold and wet steam-shed! How many hundreds break down in the effort to hold out! "I like the work, sir," said one about to leave, "but the night-work is killing me;" and the brave lad, lover of the "iron-horse," was laid in the grave in a fortnight. Boys of England! who seize every opportunity of going to the railway to see the engines, think of the night engine-boy, who is to clean the engine that your eyes rest upon. Would you like to leave your home and your parents, as night falls, to drudge, by gas-light, in and out of hot fire-boxes, to hear the clock strike twelve at night, and then, within the

furnace, eat your *night* bread and drink your *warmed-up* tea, a stranger amongst strangers?

Many a time the author has seen the silent tear roll down a lad's face on his first night from home. Let us remember the engine-boy. And let us try to suggest a plan that would, if carried out, make his calling pleasanter than it has ever been.

CHAPTER IV.

THIRD-CLASS ENGINE-BOY'S CERTIFICATE.

THE engine-boy should be registered or apprenticed for a term of years, after, say, a month's trial. Any-one with a very little knowledge of the human soul knows that it exists on hope, and that there is something within us that will, with a little encouragement, do great things. Can any one sum up or give any idea of the number of valorous deeds wrought alone by the hope of reward? Mark the truly heroic spirit, and what will it not endure for reward in the future? Clear to view is the limitless horizon to those who have hope. The hope of reward tempers the hard features of stern life, and it gives a man a certain power to stand alone and wait. How much more a dear boy? It is a low view of human life to depreciate rewards, especially rewards to be given to those who endure, who are instrumental to our pleasure. It is therefore worth consideration to entirely re-model what is unquestionably working badly, and to attempt to strengthen the individual character of the engine-boys. Recognising the fact that nothing now is held out to them to which they may aspire, it is hoped that the following suggestion will meet with the approval of railway locomotive

superintendents. An engine-boy should have a position to gain, and a position to retain.

After a period of time has passed, say, one month from the date of his engagement, all the leading traits of his character should have manifested themselves; he should, if found suitable, be asked to have his name registered in the company's books, for a term of two years; and, provided that he is agreeable to this arrangement, he should be given a third-class engine-boy's certificate, the purport of which should simply be, that he was engaged by the company, at such a date, as an engine-boy, recommended by his last employer (Mr. Sparrow), accepted by the locomotive superintendent, and agreed to by engine-boy R. Joyce.

CHAPTER V.

SECOND-CLASS ENGINE-BOY'S CERTIFICATE.

AFTER a time, he should be allowed a second-class certificate for *cleanliness*, *sobriety*, and *punctuality*.

Such a document would induce a boy to look to the main chance; he would feel that he belonged to somebody, and that he worked at something; and further he would feel that, provided that he did his work properly, there would be a prospect of his obtaining a higher-class certificate. The effect of this system would be to separate the workers from the drones, and to bring the best engine-boys to the front. Once there, they would try and stop there, and hold their position. It would come to this. A boy looks after his engine, and the engine would look after him. In point of fact, the boy would stand on his own merits. The system would not lessen the attachment of the boy for the engine. Not the least striking part of this scheme is its simplicity, and, in comparison with the existing practice of allowing so many boys to wipe down engines for a few days or a few weeks, and then away, it has much to recommend it.

CHAPTER VI.

FIRST-CLASS ENGINE-BOY'S CERTIFICATE.

MANY a boy, intended by fond parents for quite a different fate, has dreamed of rail-life, of the speed, flight, and excitement of locomotive-working.

The passion, when genuine, grows with his growth. Leaving all things else, he finds his way to the running-shed, where he wonderingly regards the great steeds in their stable, with the oily perspiration clinging to their steely limbs, travel-stained, and covered over, from the chimney-cap to the tyres, with the dust of many a far-off county. But, home returned "right." In the shed we see the calm side; only a few hours ago the engines were chopping the steam off at the chimney top, and had settled down to their hard work with the strength of a thousand horses, urged along by hot steam, flying steel, brass, and iron nerves, that laughed in their power at the elements, which in their fury gathered round the swift-revolving wheels their utmost strength to test; but they were hurled off, and, amid lightning and thunder, down, down into the deeply-cleft valleys, the "Monarch" goes with its living freight.

Onwards the steeds bound, past pools and churches, past solitary signalmen, from county to county, in the

stillness of night. All nature rests. Here and there a light is seen twinkling in the distance: maybe where eyelids are swelled with tears; maybe that of some student burning midnight oil. Through the mist, the twinkling stars shine like diamonds set in amethyst; but the cars and the iron horse onwards dash, by mile on mile, for leagues. The rolling sound is at last breaking, the sensation of crossing over some well-known bridge is experienced; the living freight rises, chatter, collect their bags, sticks, and hunt for their tickets; slowly the train rounds the curve and enters the terminus. "Well done, good and faithful servant." The engineer examines his charge, and she is put into the stable. For what? To be carefully and thoroughly cleaned. By whom? An engine-boy of the first class, whose merits and rank warrant his cleaning the engine to the satisfaction of the driver; and not that alone. He should be capable of turning his engine out a perfect picture, as an example for the boys in the lower ranks, and—as such engines attached to swift and important trains should be—a credit to every one concerned.

Further, to cultivate an honest pride, a list of engine-boys should be posted in the shed on the first of every month, giving the names in their respective classes. The list should be confined to the names of the boys who are registered—steady and determined lads—bound for the footplate.

Lastly, a good engine-boy should be well paid. The takings in some instances are not nearly sufficient to keep a lad respectably; they are most commonly paid according to age, but payment should be made according to merit. A good engine-boy should be made to

feel that his work is recognised. There is no encouragement for him to keep his engine clean, simply because he may happen to be, say, eighteen years old. No; the engines should be priced for cleaning, and the fellows who cannot give satisfaction on a large engine, should be sent to one that requires less cleaning, and commands a lower price.

CHAPTER VII.

THE FIREMAN.

HAVING looked into the case of the engine-boy, and shown that the "sample" can be improved upon, it may be expected that an equal degree of attention should be given to the individual who occupies the position next above that of the engine-boy, namely, the locomotive fireman. Looking at him calmly, it may be said that, in general, he is about as far behind the engine as the tail of the train is. His qualifications vary, of course. There are some firemen who are not very far behind, either with the shovel, or in education, but the "regular" man is, and few can deny it.

Taking the ordinary type of a fireman, if we were asked to describe him thoroughly, what he is, what he does, and what he says—to write the truth we should have to state the question thus: He is a wonderer of the engine footplate, he lifts the shovel, and when a breeze comes he swears.

There is no collision in his mind that evolves scintillation; all his collisions are with waggons and carriages. But there is good material in him. In many things he is misinformed, but of most things he is uninformed; yet he is manly and honest, with plenty of Teutonic pluck, and as ambitious a man as ever broke bread; only his

earthly aspirations fall short of the mark, he is not intellectually happy. Without inquiry, without distinction, without the faith of endurance, he pulls the long winters through, amidst wind and rain, lightning and thunder, for "siller" only. He is a big strong fireman, without a single elevating thought in his body; but with clear views and sentiments as regards the bitterness of long hours with an empty dinner-basket, and the wind blowing from the east. The outward side of his life during his hours on duty is comparatively devoid of interest to himself and to others.

The real interest which belongs to that period in a young fireman's career which we are reviewing, is the inward development of mind, growth of character, and formation of that tone of thought which will direct him right away from the meaningless slip-shod track, knee-deep with false views. Instead of the short dirty clay pipe, the half chaotic brain, we want to see him stripped of old habits and old connections, and trained to take a firm grip of a locomotive question and shake the truth out of it. Many a fault has he now! He comes on the engine footplate, off the shed-floor, familiar only with waste, oil, and tallow, and is an ardent young fool. He has trodden unheeded on many a flower; he has lived for several years in the midst of locomotive difficulties and break-downs; he is a conceited pupil, and having no purpose in view, no aim, is mist-bewildered.

He dreams that, provided he is physically capable, he is intellectually fit for the position of a locomotive fireman. And is he far wrong in this? He is nothing more than a lay figure, which can resist the bursting of a thunder-storm as it can a soft southern

breeze. It is impossible to blame him for his stoic condition of mind; he did not make it, it was made and it waited for him. Under the present system, a man can stand still like a statue and receive promotion. Where are the traditions showing a state of things that kindles enthusiasm up and down the railroad? Where the footprints that mark the rapid progress of another? Where is he that scouted ease and by self-denial rose to place, with honours thick around him? Where is the victory? Alas! for the victory; for there is no battle where it is known beforehand how the day will end. No; and it is to be regretted that there are no "stepping-stones" either; no points to lose or gain; no inviolable conditions, no competition to quicken, no rivalry to spur.

Now, what if there were? A great railway company is a colossal affair; its organization is in many respects perfect, and the business is conducted precisely in the way that the army trains its soldiers, who are animated by a high and mighty resolve to succeed. Why? Because success will demand a better-looking coat; the coat in its turn will command respect; respect will command itself. Without these symbols of the best ability, from the highest to the lowest grade, the army could not exist without danger of demoralization.

Now the locomotive department of our railways is a small State in itself, but its importance is nearly destroyed, not for want of ability, but for want of established grades in the ranks. Every railway company possesses a system in many respects peculiar to itself: we have no wish whatever to interfere with that, but in the surroundings there is nothing on a par with the high and lofty nature of the

service. The service performed by the locomotive department is well done, and upon it the destinies of hundreds upon hundreds of men, women, and children, are dependent. Practically, it is a great power in the State, and yet it is worked by men upon whom no mark of distinction is bestowed. Eminent services are rendered without any acknowledgment except "bread;" and man does not live by that alone. He requires something more that will not perish, but will shine and cheer him in winter and in summer. Men engaged in such distinguished public service as our engineers and firemen are, should wear distinguishing uniforms, in keeping with the colossal power and authority supposed to be held by our great companies.

Were uniforms to be provided in connection with certificates of capacity, the characters of the engineers and firemen would improve in quality fifty per cent. at once. And, considering that it is usual for railway companies to furnish uniforms to *all* their other servants engaged in working the traffic, it would be but an extension of their practice, not an unprecedented innovation. It would excite no sudden revulsion of feeling in the service; but, on the other hand, it would be a most consistent acknowledgment of the services rendered by our brave army of loyal engineers.

CHAPTER VIII.

THIRD-CLASS FIREMAN'S CERTIFICATE.

CAN we imagine anything more worthy of a first-class engine-boy's ambition than a third-class fireman's uniform? He would come up triumphantly to the side of the engine footplate with a certificate for cleanliness, sobriety, and punctuality; and as he had risen step by step, maintaining his superiority by new-born strength, ardour, and enthusiasm, so he would necessarily be influenced by similar motives in dealing with the details of a somewhat similar course of training on the engine footplate. He would, in fact, like nothing better in life.

Love of the engine, and a desire to understand all the laws by which its movements are regulated, would grow with his growth and strengthen with his years. The papers, pamphlets, reports, all the journals published by the scientific and literary societies, would be eagerly read, for the purpose of extending the boundaries of his knowledge. He would naturally, in fact, exhibit the same painstaking attention, application, and devotion to his duties, no matter in what sphere of duty.

"Train up a child in the way he should go, and when he is old he will not depart from it." These are true words, and they do account for much of the greasy,

filthy, and unfinished condition of many firemen at the present day.

Now, reverting to the project of granting uniforms and certificates. A third-class fireman's certificate may simply certify that the candidate can read and write, and explain the details of a locomotive engine. A key to the engine, drawn on a large scale, should be employed for this purpose.

A series of lessons preparatory to his final examination, should be given to him by a driver who takes an interest in him.

At this stage, the mode of preparing an engine for the road should be explained to him thoroughly, and not left for him to find out himself, or "pick up" from the driver. Some drivers give no definite instructions about anything on the footplate, and a strange fireman soon gets into trouble with a choked fire, &c. He thus makes a bad start and becomes a "fearful example" on the black list, and he may be heart-broken. To instruct a young fireman efficiently, he should be made to begin at the beginning. Thus he should arrive on duty about an hour before train-time, and at once join the engine. Do the talking that is required afterwards.

On reaching the footplate, he formally takes charge; but, before actually doing so, he should, as soon as possible, examine the state of the fire, of the water in the glass, and of the steam-gauge. If he find their condition satisfactory, he becomes responsible for what happens after; *but*, and this is a very important feature, if things are not all right, he should at once fetch the foreman of the steam-shed and point out all deficiencies to him. Sometimes engines have been short of steam when the fireman arrived; and, instead of going

at once to the right man, the man who should have steam up when the fireman arrives, he attempts to cure the defect himself, and the proportion of chances being against him, he fails. It is absolutely necessary to bear this matter in view; many an engine has been late at the train by such a cause. It is wonderful how many railway men get into trouble by meddling with other people's duties. The following instruction is also worth pinning to one's sleeve: Provided that the engine is properly in steam, the first thing to do, with Welsh coal, is to make up the fire with the best lumps. The fire in a locomotive fire-box, to make steam well, requires to be made in the beginning to a form resembling the inside of a tea-saucer, shallow and concave, where the thinnest part of the fire is in the centre. Too much Welsh coal swells, and it is likely to choke the fire. To obviate this result, a young fireman should try to err on the safe side, and not to put much coal on before he has acquired sufficient experience. Just a round of lumps with a few shovelfuls in the two back corners should be the extent of his firing until he knows more of the matter. The fire having been made up, the footplate should be brushed. Afterwards, the ashpan should be examined, in case it may contain a quantity of ashes; although, in well-regulated sheds, the fires and ashes are withdrawn from the fire-box and the ashpan, not carelessly but thoroughly.

The engine should then be set for oiling; the position of the cranks being as shown in Fig. 14. By attentively observing the outside rods of a coupled engine, when the cranks are both down, and when the engine is rightly set for oiling, the work of setting the engine is very much facilitated. Everything about

the engine should be done systematically, and on principle. Where there is no system there is no certainty. The oiling may be done correctly; but, to be done successfully, it is necessary to begin at one place and take the oil-syphons as they come. Leave nothing to chance. The oiling being partly completed, leaving only such syphons to fill up as can be finished at the train, the sand-boxes should be tested. This should be done before a fresh supply of sand is introduced into the boxes. Some firemen have filled up the dry sand-

Fig. 14.—Position of the Cranks for the Inspection of an Engine.

boxes first, and then tested them, when they found the sand-pipe was choked with wet sand. They were thus compelled to empty the sand-box entirely, when it had contained perhaps from six to eight hundredweight of sand. The sand discharged into the pit was lost, and their labour brought to naught. Whereas, when the pipes are thoroughly cleared first, the filling-up with sand may be completed without the risk of losing it all afterwards.

In some sheds, a man is appointed to fill up the sand-boxes; but even then the sand requires to be tested before the engine leaves the shed. As the engine proceeds from the steam-shed, the pumps and sand-pipes should all be put through their exercise and prepared for action. It is a bad sign when a fireman is seen rapping sand-pipes when with the train.

After the train has left the platform, it is the fireman's duty to look back and see if any additional signal is made, which is sometimes done to stop; and when the fireman has not attended to this part of his duty, it results that some one rather too late for the train loses it altogether. It is extremely annoying to be present on the platform, powerless to join the train, simply because the enginemen are not keeping a sharp look-out.

When on the road, it is essentially necessary to devote every thought to the engine and the traffic. The author has frequently travelled one hundred and fifty miles on the engine, on duty, and has not broken silence with his mate; each doing the work assigned to him, with the intention of doing it well. When under steam with a train, the duties of the fireman are very simple, provided that the laws of combustion are understood by him; but if he has no rule nor principle to work to, then his duties are muddled for want of a system. In many instances, a fireman is delighted with his success; and, for the life of him, he cannot explain what it is that gives him an advantage. This is a misfortune in any enterprise. To be uniformly successful, it is essential that one should know exactly what the result of one's actions will be. If we do not, we work in the dark, as we cannot be said to possess any

knowledge of the subject. We work because we work results that we expect; not because we are qualified to control the circumstances.

The laying down of such rules has unquestionably effected a deal of good; and when every fireman, before he is sent to the footplate, is told where to deliver coals, as well as the quantity necessary for each round of stoking, many mishaps are prevented. The proper practice is to fire round the fire-box; discharging one shovelful of coals into each corner, one under the door, and one against the tube-plate. This practice is applicable to *flat grates*, in which the bars are inclined from the back of the box. The front corners generally provide for themselves, and the two shovelfuls of coals which should go into the front corners of a flat box, should, on the sloping grate, be placed at the sides midway. The interval between the rounds of firing is controlled by circumstances. A light load requires but a light fire, of course; but the fire-box should not be stifled with smoke; neither should the tubes, nor the chimney. If they are stifled, the steam cannot be kept up to the "blowing-off" point; it is baffled, rising and falling and lounging in the steam pipes.

Once more, before concluding this outline of a fireman's examination for a third-class certificate. Firing should never be done whilst the train is approaching junctions or stations, nor within the stations. In boisterous weather it should be done at selected places. The water in the boiler should be kept at the level which is most suitable for keeping up the steam. The working of the train and the traffic should be eagerly scanned. Try to *find out* something. Alexander

Bennet, driver at Eastbourne, does this. "Mate," said he to another driver at Hastings, "do you know anything?" "Know anything? What do you mean?" "I mean," replied Bennet, "do you know there is a broken tyre on a wheel of your engine?" "That I don't," said the man. There was. Bennet always tried to find something; and again at Hastings, in less than a month, he found another broken tyre; and this was soon followed up by his finding a broken rail.

Try to find out something; depend upon it, things are not all perfect on a railway. There is a demand for quick intelligence; gain that, and the opportunity for exercise will come. Mark the incidents of a day on a railway, and your labours will be rewarded.

We have not entered into minute details of the occupations of a fireman, but sufficient has been indicated to determine how he should be taught at the outset. That in some instances he is not thoroughly initiated into his duties is a fact; and it has the effect of preventing his bettering himself on the footplate as he should do. But the scheme of placing a key of the locomotive engine before him for explanation, and explaining his duties to him in return, crowning the examination with a certificate, is the right way to produce a valuable fireman. Short of this, there is no distinctive feature. The service wants popularising. It is a worthy task to teach a man to love the engine and all its belongings; but, until the character of the service is raised, this cannot be effected. The engine must seize the intellect first, before the heart is charmed; and what is more likely to charm than the gift of a certificate?—a triumph in itself. No language can

tell how the youths ran at the Olympic games for the laurel wreath, and we know the scene has never to this day been surpassed. They sought not so much the laurel wreath as the approbation of their fellows gathered around them, amid gracious forms in marble, wrought as the outcome of high-reaching after excellency. We want and hope to see this spirit of rivalry amongst our engineers and firemen; but it is not theirs to find the wreath; we cannot forget that. There is, therefore, as much need for us to look for practical results from the heads of the locomotive departments, as from the men themselves. A competent master can see distinctly what the true mark of life and energy would result in.

Failures would be, as they deserve to be, exposed; and room would be left for those who approved of the new system to study the most momentous questions that would be in any way contributory to their advancement. There could be no pretended knowledge, which is an intolerable offence to a practical mechanic and driver.

CHAPTER IX.

SECOND-CLASS FIREMAN'S CERTIFICATE.

AFTER holding a third-class certificate for twelve months, and having been employed on shunting and goods engines, the fireman can be examined on all those questions that at the beginning were fully explained to him; so that all wild notions might be netted and put aside. The real business of the footplate, and the points of paramount importance, such as the preparation of the engine for the trip, and stoking to maintain steam on the road, should be questions for him minutely to answer. The object of such examinations is clear. He would work it all out in his mind, as well as in practice, and the effect would remain during his lifetime. There could be no possible doubt of his views being correct respecting his duties, and the locomotive superintendent would be enabled to form a tolerably correct opinion as to the man's capacity. There would be abundant evidence that the name of fireman as applied to him would, from his acknowledged abilities, be the strictly correct one; and with this symbol of progress a second-class certificate should warrant his being employed for some time on slow goods trains, then on fast meat or fish trains.

CHAPTER X.

FIRST-CLASS FIREMAN'S CERTIFICATE.

THIS certificate should be granted to the best firemen who have served some time on shunting engines, and been employed on the goods trains, and on slow passenger trains. This symbol of competency should be sought after by young men who desire to succeed, men who, by dint of courage and unflinching perseverance, have acquired a permanent character for being clean, sharp as a needle, and anxious to obtain the very best position as firemen, in order to attain the footplate of the best express engines, where only the cream of locomotive knowledge is to be acquired.

Promotion according to merit is the order of nature, and it should be the order in every locomotive running-shed. The man who deserves promotion should be pushed on; there may be others—drones—who object; but who heeds objections when the principle is based upon right issues? They object, indeed! As well may the lesser ornaments of a city object to terraces, statues, fountains, cascades, and such-like. As well may the sweet wild rose in the hedgerow object to its cultivated kin of the horticultural garden receiving superior notice, as that mediocrity to rail against earnestness concentrated on one accomplishment, where all the actions are evolved from one common but comprehensive principle converging towards one ultimate achievement.

A fireman before he goes on the engine footplate should know exactly what he is going to do, just as thoroughly as he knows that two and four make six. The points most requisite for him to understand are—how, and when, and where, many others have failed; and to acquire this is a great lesson. From the beginning of locomotive practice, the greatest failure has consisted in firing too heavily. The command of the shovel is a vital necessity for commanding success on the footplate. To know how, and when, and where, to fire, are three questions in which every fireman should be interested; and every effort should be made to acquire all possible information on the subject. It is certain that he should not be left to find it all out. To fire well—mechanically—a position should be selected between the fire-door and the coal in the tender, to be occupied without shifting from it. It is quite clear that, to roll about the foot-plate with the shovel is not an accomplishment, but is the movement of a man who does not choose the best and most efficient plan of handling the shovel. There remains much to be done in this matter—much discipline—before we arrive at perfection—before firing becomes an art, and is not a caprice. The shovel should be handled between the fire-box and the tender, in all weathers, as though it moved by the power of magic, gliding rapidly, empty, to the tender; moved, as it were, too hot to hold. By the establishment of a system of firing, by laying down certain rules for the use of engineers, many difficulties have been overcome, and the art of preventing smoke with extraordinary proficiency has been advanced.

CHAPTER XI.

THE ENGINEER.

THERE is not a class of men in this country like our locomotive engineers, for steady perseverance, and for achieving results by endurance, with readiness of a certain kind to meet the requirements of their employers, for working the fast and most important expresses to time; weather and circumstances permitting.

They may be deficient in something—such as a knowledge of latent heat, the nature of steam or gas to explain the principle of expansion; such as the composition of coal, strangers to the pleasure to be obtained by studying natural science. But there is in them plenty of good hearty service.

Many engineers are sufficiently acquainted with the locomotive to give every sort of satisfaction; but there are no grades in the ranks, though they are very much required.

The establishment of certificates would improve the service and also the social condition of our drivers.

The measure, no doubt, has its difficulties, like all measures of a liberal character; but that is nothing new, it was always so, and ever will be. Shall we have them? that is the point. Shall we rise above pre-

judices and old customs, and develop the service by instituting a system that has on the face of it no tangible objections; but, on the other hand, everything to recommend it? It would crown the great and mighty work of Stephenson.

Is it what he would have liked to have seen? No doubt of it. Nothing more nearly certain. After he had established the engine, most certainly, had he lived, he would not have stopped there, he would have established the engineman, who would have kept pace with the engine. Look at the facts. All the talent and administrative ability on the railways are industriously employed to improve matters. Art with all its life-saving apparatus is engaged. Plans for improved engines, improved vehicles, improved signals, and improved stations, are discussed and decided upon. Every accident which occurs is investigated, and a remedy is found for it. What for? To raise the character of the service to the highest possible standard. All is moving onwards in the hope of arriving at better results.

Provided railway directors, general managers, and locomotive superintendents were to offer their assistance—and it must come through them—to establish certificates, universally, for their drivers, firemen, and engine-boys, who would watch such a step with more interest than the public? Who would accept them with better grace than the drivers and firemen themselves? Could a gap be better filled up? If we compare the mental capacity of the engineers in the sister service—Marine—with that of our railway engineers, the comparison is overwhelming.

Of course all marine engineers at one time in their career must have graduated through the lower ranks

before they were admitted into the higher ranks, and it is only by the great interest that they took in their *own promotion* that they were raised in the service. It was not because they were the children of humble parents or otherwise, but it was because they had eyes and saw—saw what? Rank. The fact of their lowly origin served only to spur them on; it did not impair their vision. There is just as good material in the railway department of the State as in that of the Marine; but there is no rank, no coat, or gold-lace cap to attract. What does the uniform signify? It signifies that the person who wears it is a public servant intrusted with responsibility, and that the department he belongs to is more or less rendered efficient by his qualifications—natural, physical, and intellectual. Suppose we accept this definition to be the view held by the marine department, and if so the responsibility of the sister engineering department is very great. Many of our drivers are intrusted with a thousand lives in one day, about twenty thousand a month. Some might from such startling figures be inclined to think that the service is well performed: why meddle with it? The answer is, the service is well performed: why not let the driver know you acknowledge it by offering the best gift you have? Try him, and see if he will refuse it. No; the question is not whether under the present system the work is properly accomplished, but whether under an improved system it would not be better done. If the present system is *good*, the proposed system would be *better*. Anyhow, an improvement would be best for all. The highest pitch of efficiency has not been attained. The standard of qualification now is solely

height and strength combined, and it is the means of securing a very fair specimen of young men for the footplate. In many instances physical competition prevails, and the man with the biggest bone in his leg leaves many a mate behind, simply because he is a big-boned fellow.

Now, a system of issuing certificates might be admitted, on which literary competition and physical competition can be applied; and the candidate for an engineer's berth might be still better qualified than he is now, to occupy a responsible position in the railway service.

The literary element may be of the mildest character, but a little leaven, we read, will leaven the whole. It might consist of nothing more nor less than what is to be found under the respective subjects for examination in this work. Let every candidate undergoing an examination offer something in writing; also, on any subject bearing upon the point in question. Never mind if he imperfectly understands it, he will feel that he has been introduced into a new world of interest. Can any one doubt the rich literary ore there is in Mr. D. K. Clark's articles on the action of steam in the cylinder? It is impossible to conceive of any one following the calling of a locomotive-driver being indifferent to the intellectual element in that matchless description of the movements of steam before and behind the piston in the steam-cylinder. No man should lose a day without mastering it, for no doubt there are many very good enginemen—enginemen of years' standing—who at first will find it as bad as Greek to them. But let them once commit it to paper and the difficulties vanish—vanish for ever—and the

element of literary examination is attained. How? Hundreds of men do not know if they are actually acquainted with the action and modes of steam. They think they are. Let them read the account of the action of steam in the cylinder during admission, the action of steam in the cylinder during expansion, and the action of steam during exhaustion, and to hundreds of men, from no fault of their own, it contains insuperable difficulties. Then comes the tug of war, and the battle which we wish to see will tear down all the old habits and customs, and success will crown success until glorious deeds in the regions of literature are achieved by railway engineers, brought to the front by literary as well as by physical examination.

CHAPTER XII.

THE THIRD-CLASS ENGINEER'S CERTIFICATE.

LIKE the fireman and the engine-boy, the engineer in the service of the railway has nothing by which to distinguish himself. After he joins the service, if he lives long enough, he will be promoted to the position of driver, and he may, if he is smart and clean, be promoted over the heads of many others. He may be a model driver, and able to trace the history of the locomotive, very accurately; but with all that there is nothing whatever to distinguish him from the greatest ignoramus.

There is nothing of a luring nature to draw out and force a man to arrest his thoughts and apply them to a locomotive question; nor are there any traditions of alterations or improvements in the service.

For half a century, the men have been employed in England in driving locomotive engines, and have as a class discharged their duties with skill, patience, courage, tact, and courtesy. But there is a flaw in the system, and if it were removed, the service would be rendered more popular, and the men would be raised in their own estimation, and in public opinion.

What is more searching than an examination? It is

a kind of conference with one's self, and it soon throws light on that which is not all right within.

What has just been advanced in evidence that certificates are the desideratum wanting for railway engine-boys and railway firemen applies exactly, with equal force, to the railway engineer, and therefore it is not necessary to traverse the ground again.

No language can tell the effect that an efficient system of examination would produce on the service. The influence of the service would at once be raised fifty per cent. It requires no leader in the art of word-building to set up a plea in favour of this project.

It is not the want of merit on the part of the men that is sought to be benefited. Its justice is self-evident.

It is intended to mark an improvement, in keeping with the locomotive itself, and to crown half a century of driving, in which there have been great and valuable services rendered, for a heap of oily clothes and a little "siller." The present system has no vitality in it, holds out nothing to look up to, and nothing to expect; no lasting or abiding satisfaction.

The defect of which we write has no existence in the marine service, and should it exist in the railway service?

Why should it? Every man in the marine service holds a certificate of his abilities, and he can feel that it is a power to him.

Why cannot we have this in the railway service? every man in possession of a certificate: such a one, if you like, that he can hang on the wall of his "castle," and point to with native pride and say, "That is what I am".

Could anything equal this to make a man love his engine and his work?

Could anything equal this for his wife and children to look at?

Could anything equal it to say to a government inspector in answer to his question, What are you? "First-class engineer, sir?"

If certificates were recognised, there would be no longer the marked diversity of appearance in the men that we see now. The best men would come to the front, drawn as the magnet draws the needle.

Here, then, we shall get a good man, a superior article, as transparent as crown-glass, with all sides alike, and without a flaw. Step by step, he will rise alongside the engine, and his degree will follow; proud of his work, he can face any one. There is, in an examination of this kind, something tangible and satisfactory to men. He has read his lesson and is free to go. If it is thought necessary, let him write the matter out, and bring the document before his examiner; this will be of excellent use.

On his foreman's recommendation, the candidate for a third-class engineer's certificate should pass an examination in the following subjects:—

SUBJECT 1.—SIGNALS. To describe the use and proper observance of all signals.

1. Semaphores 2. Flags 3. Personal	Day.
4. Lamps (lights) 5. Percussions	Night.

SUBJECT 2.—ENGINES. To describe the classification

of locomotives; showing that there are two kinds of locomotives, namely, those having inside cylinders, and those having outside cylinders; and that they are distinguished as single, or coupled: single engines, when the driving-wheels are free to act by themselves; coupled engines, when the wheels are connected together by coupling-rods; coupled in front when the leading and driving-wheels are connected; and coupled behind when the trailing and driving-wheels are connected. Locomotives that carry bogies in front, or behind, are known as bogie-engines. The use of the bogie is to enable the engine to traverse curves nicely, and with the minimum of friction.

Tender-engines are such as have vehicles for water and coal behind them. Tank-engines are such as have the supplies of fuel and water carried on the engine-frame.

SUBJECT 3.—BOILER. To describe the boiler. The boiler consists of six parts, namely, the barrel, the fire-box, shell, tubes, smoke-box, and chimney. The barrel is made of three rings of plates. When the longitudinal seams are made with a butt joint, the planed edges of the plates come together flush. Lap-joints are made when the plates overlap each other. The joints are held together with rivets, and the connection is made between the smoke-box and the barrel by an *angle-iron* ring, to which also is united the *front* tube-plate. At the other end of the boiler is the fire-box *casing* or *shell;* at the front it is fastened to the barrel, and at the box to a *foundation-ring*. The back-plate of the casing contains the fire-door and the gauge-cocks, and other footplate furniture.

The *fire-box* is within the casing, and is generally made of copper. The tube-plate is made stronger than

any other portion of the box, in order to carry the tubes; the back-plate is cut out so as to form the fire-doorway with the *mouth-pieces;* the fire-box is secured by copper stay-bolts to the sides of the shell, and by iron rivets to the foundation-ring; the roof of the box is secured from coming down by over-heating, or by over-pressure, by ribs laid across the box, or by stays to the shell. The lead-plug has a small hole drilled through its centre and filled with lead, which melts when the water is allowed to leave the crown of the box; the plug being screwed in through the plate, and projecting inside the boiler to some little distance above the crown of the fire-box, the plug is then carried upwards to give notice that there is danger of burning the copper. The tubes extend from the fire-box to the front tube-plate; generally made of brass, they are expanded at the ends and made water-tight in the fire-box end. Ferrules are driven in, which strengthen them. The smoke-box is secured to the front tube-plate and framing.

The door of the smoke-box is secured by a pinching-screw and cross-bar, and the latter is made to be taken out. It is supported by carriers that are riveted inside the smoke-box.

The chimney-top is sometimes fitted with a cap, with the object of turning aside the wind and to help the exhaust-steam and smoke to escape. The boiler-mounting consists of the following:—Clack-boxes, through which the water from the tender or tank passes to the interior of the boiler. The gauge-glasses show the height of the water in the boiler; water enters through the lower cock, and steam through the upper cock. The whistle, plugs, &c. form the remainder of the mount-

ings. The safety-valves discharge steam of such excessive pressure as is thought not safe for the boiler. There are spiral springs and levers used to hold the valve down.

The regulator is fixed within the boiler, and through it the steam is allowed to pass, when it is opened by the driver, into the steam-pipes, which are in direct communication with the interior of the steam-chest which contains the valves. The steam-pipes are generally of copper.

Subject 4.—Framing and Motion. To describe the carriage and motion of an engine. The longitudinal framing-plates are sometimes double; two slabs are fixed on each side of the engine. When there is only one slab on each side it is called a single-frame engine. The cylinders are of cast-iron, and are fixed between the frame-plates by bolts. The frame is also braced together by the motion-plate, and by transverse plates before and behind the fire-box. The horn-blocks are fastened to the frame-plates, and the axle-boxes work up and down with them. The slide-bars carry the cross-head on the end of the piston-rod. The piston is in the cylinder, and carries the rings that prevent the steam blowing through from one side of the piston to the other.

The crank-axle is supported in driving-boxes. Sometimes there are boxes on each end of the axle, inside and outside. It is only so with a double frame; the *big-ends* are the bearings for the brasses of the connecting-rod end; between the cheeks of the big-ends the excentric-sheaves are fixed. The cranks are at right angles to each other; and, when one is on a dead centre, the other is in full throw. The excentric-straps are

fitted on the sheaves, which revolve within them; the excentric-*rods* that are joined to the top of the link are the fore-gear rods; those at the bottom are back-way rods. The expansion-links are in some cases curved, in some cases straight. The curved link is called a Stephenson link, the straight link Allan's link, and a box-link Gooch's. When the excentric-rod is in as nearly a straight line with the valve-spindle as it is possible to get it, the engine is said to be in full gear. This is so with reference to either fore gear or back gear.

Inside the expansion-link the die works, connected to the valve-spindle; the valve-spindle extends inside the valve-chest, and is fitted with means to move the valves over the opening to the interior of the cylinder. The valves are made to cover the ports, and sufficiently more than this to provide lap. There are two openings into the cylinder, the front port and the back port; the middle port on the cylinder-face is the exhaust-port, and it opens to the chimney and the atmosphere; only one steam-port at one time can be open to the exhaust. The steam in the cylinder from one side of the piston leaves it by the same way as it entered, when the valve uncovers the steam-port inside and ascends the chimney. The inside edges of a valve let the steam out of the cylinder into the chimney. The outside edges of a valve let the steam out of the steam-chest into the cylinder.

The exhaust-steam, ascending the chimney, induces the air to quit the smoke-box, and there is created a partial vacuum; the gases in the tubes rush into it, and those in the fire-box in their turn enter the tubes, whilst the fire-box is supplied with air from the ash-pan.

CHAPTER XIII.

THE SECOND-CLASS ENGINEER'S CERTIFICATE.

As the examination of the third-class locomotive engineer was designed to find out what he knew of the engine, and how much pains he had taken to become acquainted with it, so the examination for the position of second-class engineer should be conducted for the purpose of ascertaining what his views are respecting an engine-man's duties with an engine, and what he has done towards perfecting the art of locomotive-driving.

When brought up for examination, for the purpose of passing as a driver for the first stage, it was not expected that he could know anything of the experience of a driver, and therefore questions relative to working of an engine in steam—in full "go" with a train—were not put to him. He could know nothing whatever of the driver's side of the engine; he could know that by opening and shutting the regulator and keeping a good look-out, the engine could always be brought home with a whole buffer-plank, but he knew nothing of the working, the scheming, and foresight that a man—an engineer—in charge of an engine had to exercise to achieve such a result. Of this he was quite ignorant; but having spent some time on the engine-footplate and *felt* the responsibility of his

charge, and worked off all timidity on shunting and goods-engines, he is or he should be in a position to say something that should lead his superintendent to offer him promotion. Upon what? Upon the very best of testimony—namely, that of progressive experience and class-examination. And the true ring of the material would be detected. Would a man venture to face an examination who knew thoroughly well he would be plucked? Would a man fear who knew thoroughly well he should not?

As with the third-class certificate, the matter which is about to follow that is proposed to form the subject of examination may, if it is thought proper, be written, and the examination may be completed *vivâ voce.* If the man writes his subject, it will make him only more perfect, and there is nothing like writing a matter out to fix it on the mind. Bacon said, "Reading makes a full man, conversation makes a ready man, writing makes an exact man."

SUBJECT 1.—WITH A TRAIN. To describe the chief points for attaining success. The first and most important duty of a man when in charge of an engine is to devote his whole heart and soul to its working; with a piece of machinery, it is true, as in most other things, that a good beginning makes a good ending. The chief thing to aim at with a locomotive engine about to be attached to a train is to insure a good start: by first examining the engine, and, secondly, by the management of the fire.

It is not uncommon for engines to fail from causes over which the "engineer" had control. Such failures could have been prevented had he examined his engine systematically before leaving the shed. It is im-

possible to mention all cases in which engines have failed; but most of those failures, which have been traced home to some piece of negligence, could have been prevented before the engine had joined the train.

To inspect an engine properly, so as to detect defects in the machinery or the arrangements of the engine, the inspection should be done by commencing at one end of the engine and by following up the inspection until the end of the other side of the engine is gained. And again, when leaving the shed, the condition of the engine generally should have particular attention, to see that the sand-pipes, pistons, and valves work properly.

Next to the condition of the engine is the condition of the fire.

To depend upon the fire for making steam, it should be well burnt through at the start, provided that Welsh coal is used. If black coal is used, a fire should be put on of sufficient depth to suit circumstances before leaving the shed; so that the smoke, or the greater portion of it, may be expelled, and may not become a source of nuisance in the station. It is possible to keep under the smoke if proper steps are taken in time, not unless.

The form of a fire should be concave, and the coals should be placed at first, and while the engine is running, round the fire-box. The oiling demands care and frugality; the causes of heating are various, and so far as the engineer is concerned all he can do is to see that all the trimmings are in good order and properly supplied with oil, and that the syphon-cups and axle-boxes have sufficient access for air. The management of the engine with a train is controlled

by the regulator, and the regulator is under the charge of the engineer.

The regulator should be judiciously handled, not only at the start but throughout the trip, so as to keep the water from penetrating into the cylinders. The trip should be performed to time, and without sudden snatches by notching the engine up with the steam on. This action should be avoided; so also should the action of starting suddenly from a station.

The steam should not blow off at the safety-valves, nor should the engine be short of steam, but the pressure both of that and the boiler should be kept at the working figure. To maintain steam on the road, the fireman, who should do all the firing required in first-class practice, should supply the wants of the boiler, or fire-box, with coals in such quantities as to prevent smoking, and the depth of the fire should be regulated by the load on the piston. The efficiency of a fire will depend more upon the latter conditions being followed out in practice than upon anything else that can be mentioned in relation to firing. A choked fire is due to the fireman over-estimating the load on the piston, and it may stop a train as effectually as a hundred waggons will. While the train is under "steam," the attention of all on the engine should be given to it.

Any irregularity in the working of a train should be investigated, to ascertain how the irregularity is caused. The engineer of a late train should make signals indicating the safety or non-safety of the line to passing trains. In breaking down, either with an engine or train, if anything is to be disconnected it should not be done where there is another engine near,

but the disabled engine or vehicles should be shunted into a siding at once. Uncoupling engines must be a subject of preparatory study, so that at the time of failing no time may be lost in making necessary arrangements. The coupling-rods, if one breaks, must both be taken off; and if a piston or a valve fails, the corresponding side of the engine must be disconnected altogether. If an engine is prevented from working by the failure of a piston or a valve, when both are disconnected from their respective connections they should be pulled right back, and fastened there. This will not occupy much time.

Every failure that occurs should be investigated by every engineer in the service, to inform himself, and if anything is particularly striking it should be noted.

In providing remedies for failures the least possible amount of time should be consumed.

The train should at all times be under proper control, and in foggy or thick weather the engine should not be run at a higher speed than such as may admit of the train being stopped within danger-signals.

SUBJECT 2.—COMBUSTION. Combustion is the result of the chemical attraction in different degrees which exists between various elementary bodies. This may be well demonstrated by supposing a locomotive fire-box containing green fire, with the damper and the fire-door closed.

There are gases in the fire-box consisting of carbon and hydrogen; and there are gases outside—oxygen and nitrogen, in air. There is a chemical affinity between these bodies which is a species of attraction, and exhibits its importance immediately on opening the door. The air enters, and the gases unite with a slight explo-

sion due to the expansion of the gases, and flame is the result, consequently combustion. If there were no chemical affinity between the gases, there would be no explosion, no haste to evolve fire. Oxygen is the principal supporter of a fire, and the gases in the coals may be burned imperfectly, for want of more air—oxygen. If the air admitted is deficient in quantity, large volumes of smoke pass away through the tubes containing the distilled essences of the fuel, which being heavily charged, lounge on the way to the atmosphere and deposit accumulating quantities of soot in the tubes and the smoke-box.

Smoke is formed by the carbon, which is evolved from the coals, not having received its proper proportion of oxygen from the air. That want of air is the cause of smoke is demonstrated by opening the fire-door a little when the engine is smoking; the admission of more oxygen, or air, causing better combustion and reducing the smoke. When the oxygen of the air with the carbon and hydrogen in the fire-box are mixed and united in proper proportion, the heat is intense, and is sufficient to burn the carbon and hydrogen completely.

This also is demonstrated by results. When the fire-box becomes bright with heat, and no smoke is leaving the chimney, the boiler generates more steam. It may be noticed that when a fire-box is white hot, the heat causes the combustion of the soot which may be hanging about the tubes and the smoke-box. Imperfect combustion clogs the tubes with carbon; perfect combustion cleans them. Carbon is found in many forms; it is obtained from oil as well as from coal. It is contained in tallow and in candles. If the

hand is placed over a lamp to exclude the air, carbon is deposited instantly; that is a very good proof that air consumes it. The appearance of smoke issuing from a chimney-top is evidence that the volume of air, and consequently that of oxygen, admitted to the fire, is not sufficient to supply the amount required to enter into chemical combination with the gases in the fire-box.

If more air with its contained oxygen be admitted to the fire, the gases there will at once burst into flame; or, in other words, the oxygen will combine with them, thus: the hydrogen, coming off pure and in combination with carbon, unites with the oxygen to form water, the carbon takes another portion of the oxygen to form carbonic-acid gas, and the remainder of the carbon passes off in a state of very fine division, as smoke; and hence the process of smoke consumption consists practically in supplying a further amount of oxygen to this carbon going off and consuming it, and thus forming another portion of carbonic-acid gas.

The quantity of atmospheric air necessary for the chemical combustion of one pound of an average coal is about 11 lbs.; but, in practice, a much greater quantity of air is required, for a large proportion is carried through the fire unused, by the force of the blast.

To consume the smoke in the fire-box—and as a matter of fact it can be nearly all consumed—it is required that the fire should not be too deep for the load on the piston; otherwise, the blast may be checked at the grate-bars. It is a mistake to allow the gases which are given off to burn within the tubes by the dampers being shut; for the chemical action takes place too late, and a portion of the carbon escapes.

The principal conditions of the successful management of a locomotive fire are: 1st, Always to fire a little at a time, so that the amount of coal put on the fire shall never be so great that the quantity of gases given off is in excess of the proportional amount of oxygen, supplied by the air, required to combine entirely with them, and thus perfectly consume them.

If they are given off in such excess, they pass away unconsumed, and thus waste of fuel is occasioned.

2nd, Always to so regulate the quantity of air passing through the fire, that there shall be sufficient oxygen supplied to completely combine with the gases, and that there should not be an excessive draught to the fire so as to permit the escape of a considerable amount unconsumed. The fact of the steam-pipes, blast-pipe, and walls of the smoke-box being thickly coated with carbon, together with the amount of smoke one often observes issuing from an engine, are evidence that something is wrong somewhere, either in construction or management; and that, at any rate, a larger amount of the carbon, and in all probability other valuable inflammable heat-generators, pass away unused and wasted.

SUBJECT 3.—COAL AND STEAM. *Coal* is a carbonaceous substance, found lying in strata at various depths beneath the surface of the earth:—In England, France, Germany, Sweden, America, Australia, and India. The best quality of coal is found in Great Britain, in various parts of England, Wales, Scotland, and Ireland. These are all different in respect to their composition. The least inflammable kind is the Welsh coal, much used in English locomotives. It requires a considerable degree of temperature and of good management to get all the

heat-value out of it; but when it is properly consumed, it produces very little smoke or flame; and, if properly supplied with air, it will not clinker. It is the best coal for railway service. It has been found by analysis to contain a greater proportion of carbon than the bituminous coals, and it does not cake so rapidly in the fire-box.

Bituminous Coal.—Newcastle or Derbyshire. It requires a large grate to burn it thoroughly, and its greatest evaporative performance is only achieved when it is supplied in small quantities at a time to the fire-box, at frequent intervals, to prevent its clinkering. The draught of air from the grate should be allowed to have free course through it, and plenty of air should be supplied above, through the fire-hole doorway.

Steam is generated from water at or above the temperature of 212°. When a fire is placed under an open vessel of water, the water absorbs the heat from the heated plates, and when sufficiently heated it ascends in bubbles of steam, which collapse below or near the level of the water; as these globules ascend, fresh quantities of water descend and take up the heat, and ascend also; and the ascending and descending operation goes on until all the particles of water are of the same temperature. Then this operation ceases and another commences, and this takes place when the temperature of the water is 212°. The tremor or thumps heard in a vessel before the water boils arise from the heated globules of steam collapsing within the incumbent mass. This action is particularly violent when steam is blown back out of the boiler into a tender filled with cold water. It is produced by thousands of vesicles of water collapsing at the same moment. As soon as an experienced

driver turns the steam into the tender, he can judge by the tremor which follows in the water, whether the water in the tender is cold, warm, hot, or boiling. Provided that the vessel in which water boils has no cover to it, and is open to the atmosphere, all the heat that can be applied under it would not increase the temperature of the water above 212°, and the steam given off would be of the same temperature, 212°. The harder the firing, the more steam is made away in the same time. No other result can possibly be obtained. The reason of the stationary character of the temperature is that, at 212°, steam can resist the pressure of the atmosphere, and it therefore leaves the surface of the water.

In a locomotive boiler the steam is simply confined, and it accumulates until it reaches the desired pressure. Steam of 120 lbs. pressure per square inch has a temperature of 341° Fahr.,* and that of the water also is 341° Fahr. The steam and the water have the same temperature. The pressure of the steam is equal in all directions, and reference is made to this property when it is stated that a boiler has so much pressure per square inch. If a boiler is pressed to 140 lbs. there is 140 lbs. pressure on *every* square inch in the boiler exposed to the steam. Steam is invisible and colourless, hence there is no evidence of steam being in the boiler by looking at the gauge-glass. It is also elastic, and it is this property of elasticity that renders it so serviceable in the steam-cylinder.

When the regulator is opened, the steam from the boiler flows at once into the valve-chest, and if one of

* See Properties of Saturated Steam, in the eighth edition of the "Encyclopædia Britannica," article Steam, by Mr. D. K. Clark.

the steam-ports is uncovered by the valve, it reaches the cylinder. If there are many bends in the pipes, or if the pipes are colder than the steam, there will be a difference between its temperature and that of the steam in the boiler. But the total pressure at the rate of 120 lbs. pressure on the face of an 18-inch piston-head is more than thirteen tons, and if it should not require so much as that pressure to balance the resistance of the engine and train, the piston will be pushed along the cylinder to the other end by the steam.

The action of the steam in the cylinder has been investigated by Mr. D. K. Clark, by a series of experiments made on a number of locomotive engines of various classes, and the results of those investigations were first published by him in "Railway Machinery," 1851-55. These were the first experimental demonstrations made into the behaviour and condition of steam in the cylinder, and they remain to this day a standard of reference for all such inquiries.

SUBJECT 4.—To describe the action of steam in the cylinder.*

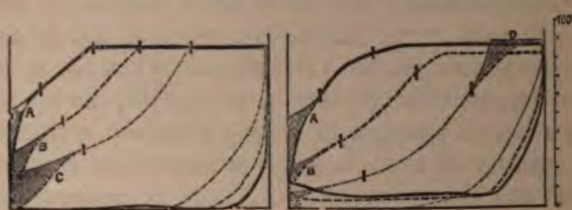
The Action of Steam in the Cylinder during Admission.—In the flow of steam from the boiler to the cylinder, it meets with hindrances to its passage which usually operate to cause a considerable reduction of pressure when it reaches the cylinder, even if all the passages be thrown wide open. The actual charge of steam transmitted through an irregular passage of considerable length, and of a given sectional area, is, in all cases, less than what can be passed through an aperture of a very short length, as, for example, an

* Abstracted from "Railway Machinery," pp. 69 to 96. See also "Steam and the Steam Engine," pp. 265 to 273.

aperture in a thin plate of the same sectional area, owing to the bends and lateral friction of the long passage. It therefore frequently happens that the opening of the port allowed by the valve, though it may be much less than the total area of the port, is sufficiently large to pass all the steam that can force its way along the passage. This fact is constantly exemplified in practice: it is known that the opening of the port beyond a certain amount, which is in all cases less than the area of the port itself, ceases to be advantageous in facilitating the passage of the steam into the cylinder. Similarly, the opening of the regulator, or "throttle-valve," beyond a small fraction of the sectional area of the steam-pipe, does not add to the available pressure in the valve-chest. When the steam is not dry, containing water in suspension, the labour of moving in passages is greatly increased, owing to the quantity of dead, inelastic weight to be dragged along; and the reduction of pressure is consequently much more than with dry steam.

Directing attention, for the present, to the behaviour of steam within the cylinder, it is to be premised that, notwithstanding the objection that has been urged against the ordinary slide-valve, worked by an excentric motion—the want of sufficient celerity of action—there is no material wire-drawing of the steam by the closing valve when the period of admission exceeds two-thirds of the stroke, unless at very high speeds of piston, exceeding from 500 to 600 feet per minute. When the steam is cut off at shorter periods, however, the travel of the valve being less, and therefore, also, its velocity of motion, the wire-drawing increases at high speeds, though at low speeds it does not. For example,

the indicator-diagrams (Figs. 15 and 16) were taken from a locomotive-cylinder 18 inches diameter, 24 inches stroke; steam-ports 13 by 2 inches; exhaust-port 13 by $3\frac{1}{2}$ inches; lap of valve outside $1\frac{1}{4}$ inch; inside $\frac{1}{16}$ inch. Each figure shows three diagrams for periods of admission, respectively 16, $11\frac{3}{4}$, and 7 inches of the stroke, the terminations of which, and of the expansions, are pointed off on the figures. For the first figure, the speed of piston was 240 feet per minute; for the second, 770 feet per minute. The wire-drawing at the lower speed was obviously nothing; at the higher speed, the pressure fell 3 lbs., 12 lbs., and



Figs. 15 and 16.—Indicator-Diagrams.

25 lbs. below the initial pressure, before the steam was cut off: doubtless explained by the fact that, in the three cases, the travel of the valves was respectively $4\frac{3}{4}$, $3\frac{15}{16}$, $3\frac{7}{16}$ inches; and the maximum opening of the port was $1\frac{1}{32}$, $\frac{11}{16}$ nearly, and $\frac{1}{2}$ inch. It was found, however, that, in the third case, with the shortest admission, the steam-line was practically straight and parallel to the atmospheric line, at speeds of piston up to 450 feet per minute. In inferiorly arranged engines, with short lap and short travel of valve, wire-drawing is considerably greater than in the example just illustrated. With the same sizes of cylinders, a $\frac{5}{8}$-inch

lap wire-draws considerably more than 1-inch lap of valve.

Long lap, in conjunction with wide ports, reduces the wire-drawing to a minimum. The more dry the steam is, the more susceptible it is of apparent wire-drawing, as indicated in the cylinder, because dry steam enters the cylinder more freely than wet steam, and attains a higher initial pressure.

As to the quantity of lead of the valve needful to insure ample and timely admission of steam into the cylinder at the commencement of the stroke, one-fifth of the length of the steam-port is sufficient. When the lead is excessive, the steam is admitted so readily as to be momentarily compressed, and to cause, in some cases, an unfavourable pulsatory action of the steam. The total absence of lead likewise occasions an unsteady pulsatory action in the cylinder. If lead is deficient or wanting, the maximum pressure of steam in the cylinder is not attained until after a portion of the stroke is traversed by the piston.

The Action of Steam in the Cylinder during Expansion.—When steam is admitted into the cylinder while the latter is comparatively cold, or colder than the steam, a very sensible condensation of the steam takes place during admission, in the process of heating the cylinder to the temperature of the steam, which continues to a certain extent during the period of expansion. A portion of this heat, though but a small part, passes off and is lost; the remainder is retained by the cylinder until it is re-absorbed by the precipitated steam, during the expansion of the remaining steam, if it be long enough continued; that is, until the temperature of the latter falls below that of the cylinder.

This is a destructive process, occasioning an absolute loss of steam; and the amount of steam thus injuriously precipitated, and but partially revived, increases rapidly in proportion as the steam is earlier cut off, and expansion is extended. In the cylinders of ordinary steam-engines the extra consumption and waste of steam devoted to the heating of the cylinder in the first part of the stroke is above 12 per cent. of the whole steam consumed for a period of admission of one-third of the stroke. In exposed locomotive-cylinders the loss is proved to amount to nearly 40 per cent. of the whole steam consumed, when cut off at one-eighth of the stroke.

This important species of loss is inseparable from the attempt to work steam expansively where there is no provision for the heating of the cylinder, and maintaining it at a suitably high temperature—equal at least to the initial temperature of the steam. The magnitude of the loss is so great as to defeat all such attempts at economy of fuel and steam by expansive working, and it affords a sufficient explanation of the fact, in engineering practice, that expansive working has been found to be expensive working, and that, in many cases, an absolutely greater quantity of fuel has been consumed in extended expansive working, while less power has been actually developed.

With respect to the ratio of pressure to expansion of steam in cylinders, observed in ordinary practice, it may be sufficient to remark in this place that the quantity or weight of steam in the cylinder is the same throughout the process of expansion, estimated in terms of the pressure and the volume of steam, as saturated at different points of the stroke, when the steam is dry

and the temperature of the cylinder is properly maintained; and that, consequently, the pressure of expanding steam in a cylinder, under such circumstances, may be determined with sufficient accuracy for any degree of expansion, in terms of the ascertained density of saturated steam. On the contrary, in cylinders imperfectly heated, where the steam is partially precipitated during admission, and during the first part of the expansion, the expanding pressure at first declines more rapidly than would be due to the maintenance of a constant quantity of steam, and afterwards less rapidly, rising above the expanding line of pressure proper for a constant weight of steam—equal to that contained in the cylinder at the commencement of expansion. This want of conformity is exemplified in a diagram, Fig. 17, taken from an outside-cylinder locomotive, with a stroke of 24 inches, at a low speed, in which the dotted lines show the expansion-curve which would have been described with a constant weight of steam. This process of successive condensation and re-evaporation is distinctly indicated, for no sooner is the steam cut off at A than condensation is made visible by the vertical sinking of the expansion-curve below the standard or normal curve, until the temperatures of the steam and the material of the cylinder become equal, when, as the pressure continues to fall, and the temperature of the steam with it, the curve rises and crosses the normal curve at C in virtue of a partial re-evaporation of the steam previously precipitated, caused by the cylinder itself, which, at first colder than the

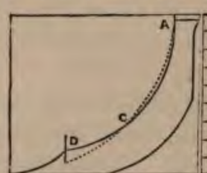


Fig. 17.—Indicator-Diagram.

steam, and heated by it in the first stage of the expansion, becomes then relatively hotter, and partially restores the heat of which it had previously robbed the steam. The process of restoration of heat goes on to the end of the expansion, as further proved by the increasing excess of the indicated above the normal pressure at the point D, amounting to above 10 lbs. per square inch at the point of exhaustion.

That the condensing power of an unprotected cylinder is something very considerable, is rendered very obvious by an indicator-diagram, Fig. 18, taken from the same cylinder, in full gear, at a low speed, shortly after starting with a train. It shows that the pressure could not be maintained in the cylinder, as condensation in heating the cylinder proceeded faster than steam could be supplied through the opening of the port. Had the cylinder been hot, the pressure would have been fully maintained, according to the dotted line.

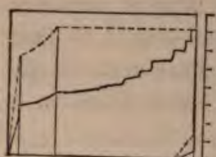


Fig. 18.—Indicator-Diagram.

The Action of Steam in the Cylinder during Exhaustion.—In no part of the distribution is the advantage of time more apparent than during the period of exhaust. It is plain, by reference to Figs. 15, 16, that the steam does not discharge itself instantaneously from the cylinder at the point of release, as the piston, in all diagrams, has visibly to go some distance before the pressure falls to a minimun. In the left-hand figure, at the lower speed, the piston moves $3\frac{1}{3}$ inches from the point at which the steam is released, to the point at which the pressure falls to the atmospheric line. At the higher speed the steam only reaches the

minimum pressure of 2 lbs. when the piston has attained to the end of the stroke, through 5 inches of the cylinder. These are elementary proofs of the benefit of time for insuring a good exhaust.

As the velocity of steam escaping uninterruptedly would practically suffice to evacuate the cylinder in good time, to prevent the evil of back pressure, there is no doubt that the back pressure which does actually arise is owing to the circumstantial hindrance of mixed water, strictures, bends, and friction. The retarded motion of the piston towards the end of the stroke, in virtue of the action of the crank, is peculiarly favourable for the exhaustion of the steam, as it allows time for its escape before the piston returns upon it. At the higher speeds, however, the escaping steam may be overtaken and driven before the piston into the atmosphere, should its remaining elasticity prove insufficient, and then an opposing back pressure is established. The wider the lead for the exhaust the less is the back pressure, on account of the increased facility for escape. For the usual speeds of pistons of stationary engines—from 220 to 300 feet per minute—the back pressure is inconsiderable, if the cylinder be properly heated and the steam be dry. On the contrary, the back pressure is very great when the steam is condensed within the cylinder, or if it be loaded with water by priming.

The evil of condensation in a cylinder, in causing back pressure, was clearly proved in the case of a locomotive, into the cylinder of which steam was admitted at 80 lbs. pressure above the atmosphere, cut off at one-sixth of the stroke and exhausted at half-stroke. It was so loaded with water when discharged that it

incurred a back pressure of 12 lbs. per square inch in being expelled by the piston, which was moving at an average speed of 430 feet per minute. Shortly after, when the steam was admitted in a much greater volume, through half the stroke, at a speed of piston of 580 feet per minute, the exhaust pressure only amounted to about $2\frac{1}{2}$ lbs. per square inch. The cylinder had been previously heated by hard work; the steam was comparatively dry; and the opposing pressure was, consequently, almost entirely removed.

The ordinary effect of the priming of muddy water from a locomotive boiler is illustrated by Fig. 19, in which are shown indicator-diagrams taken from the cylinder immediately previous and subsequent to blowing-off the boiler, when the water had been unusually impure, at the same speed of piston, about 600 feet per minute. The full line was described before, and the dot-line after, the boiler was supplied with clean water; and, other circumstances being the same, the back pressure fell from 9 lbs. to about $1\frac{1}{2}$ lb. per square inch above the atmosphere. In some cases the priming of water into the cylinder has been found to reduce the effective pressure more than a half.

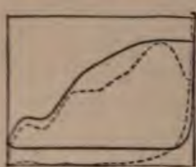


Fig. 19.—Indicator-Diagrams.

Summary of Data as to Back pressure.—If the steam working in steam-engines could escape freely without resistance, the back pressure would be simply the pressure of the atmosphere in non-condensing engines; and in condensing engines it would be the pressure corresponding to the temperature in the condenser—what Professor Rankine calls the "pressure of condensation." The mean back pressure, however, always—sometimes

considerably—exceeds the pressure of condensation. One cause of this, in condensing engines, is the presence of air mixed with the steam, which causes the pressure in the condenser, and also the back pressure, to be greater than the pressure of condensation of the steam. The ordinary temperature in the condenser, in proper working order, is about 104° Fahr., for which the pressure is 1·06 lb. per square inch, whilst the actual pressure in the best condensers of ordinary engines may be scarcely ever less than 2 lbs. on the square inch. The principal cause, however, of increased back pressure is resistance to the escape of the steam from the cylinder, amounting to from 1 lb. to 3 lbs. per inch greater than the pressure in the condenser. There is no doubt that, practically, in condensing engines, the back pressure increases with the speed of the engine, and also with the density of the exhausted steam, and with a reduced size of the exhaust-ports. In locomotive engines, which are non-condensing, Mr. Clark has found that the excess of back pressure above the atmospheric pressure varies nearly as the square of the speed, as the pressure of the exhaust steam at the commencement of the exhaust, and inversely as the square of the area of the orifice of the blast-pipe; that it is less the greater the ratio of expansion; that it is less the longer the time during which the exhaustion of the steam lasts; and that it is increased by the presence of liquid water amongst the steam.

CHAPTER XIV.

THE FIRST-CLASS ENGINEER'S CERTIFICATE.

There is no royal road to fitness for the responsible work of locomotive service.

Promotion is attainable only by dauntless pluck, great power of endurance, readiness of resource, intelligence, and steady perseverance. Mere theoretical knowledge would never make an engineer rise to a high position; whilst, on the contrary, a man may have a reputation as a driver, and yet may have no special qualification such as one might think would distinguish him and would enlarge his mind, and raise the standard of intelligence.

Exercising self-help and self-reliance, and with a mind somewhat developed into a state of efficiency, the qualifications required of a second-class engineer to obtain his certificate might go far to raise the status of locomotive engineers throughout the kingdom.

If we look back by the way we have come, it will be seen that at each step something was required of the engineer to enable the superintendent to form an opinion of the candidate's interest in his work.

In fact it is so arranged that a man becomes his own examiner; that is, knowing what is required of him, he drills himself into his work.

And why? To take higher rank, and take it creditably.

How often has it happened that ignorant and conceited drivers, having no capacity themselves, have propagated the evil of imperfect qualifications by their inability to explain to the firemen under them the general principles of the engines. There is not one driver in a hundred who ever thought of showing a fireman under him, just about to be promoted, how to test valves and pistons; or why engines are described as left-hand or right-hand engines; or of explaining the laws that regulate the combustion of fuel in the fire-box.

Why is this so? It is because the service is not animated by the spirit of inquiry.

It is therefore the object of these pages to deal with the question, with every question, that is likely to excite the spirit of inquiry.

As he would be a very peculiar railway man who would occupy such a position as we have sketched out without knowing, by the time he is fitted for receiving a first-class certificate, all about the engine and its working, we propose that he should on taking his second-class certificate pass a final examination in locomotive questions, and with a view to that point, the plan has been all along, from the beginning of his career as an engine-boy, to get all this matter thoroughly settled, and so leave the way open between the taking of the last certificate and the previous one to allow him time to make himself familiar with something higher than mere locomotive-working, something that he is not compelled to know in order to work an engine, but which thirst for knowledge has induced to acquire.

Experience is gained by mechanical attention to every-day duty, but intelligence comes through investigation.

We will therefore now enter into the realm of thought, and leave the business of the shovel and the regulator, and endeavour as clearly and lucidly as possible to deal with the questions involved, more or less, in the manufacture and the management of the locomotive engine.

Anything appertaining to the locomotive is to a thorough engineer in the highest degree a model, full of interest. Anything that contributes to enlarge his stock of information, contributes to his happiness.

SUBJECT 1.—COMMON PROPERTIES OF BODIES. *Adhesion* is a resisting force, and it differs from cohesion. It is more or less powerful according to the nature of the bodies in contact with each other, and is approximately proportionate to the pressure between the surfaces. It affects everything without regard to bulk or figure. In the locomotive, it is a pressure in a downward direction, and is caused by terrestrial gravity, by which all bodies tend towards the centre of the earth. If it were not so, all things would be in a state of suspension, and an engine placed upon the rails on its wheels would not move ahead. The mass, engine, acted upon by gravity is drawn downwards; hence, weight, and for our convenience we support the engine on *points*. If these points were perfectly smooth, the engine, though impressed with a downward pressure, would slide easily. If the points are rough or mixed, there is a resisting power and the adhesion is increased. By the application of external force, the resistance may be overpowered.

There is another kind of adhesion besides that caused by gravity, or weight, and one or two illustrations will suffice. Faced-up joints brought together with a little oil or tallow between them will require a slight force to separate them. Sealing-wax will adhere to paper.

Cohesion is the force by which the particles of a body are held together, and form solid masses. The driving-wheel of an engine is just as much a number of atoms as it is a number of "faggots," and the atoms can be separated in many ways; but it is sufficient for the present purpose to state that filing is one way of separating particles. The intensity of the cohesive force varies in different bodies, as may be observed in filing lead compared with the filing of iron; and filing iron as against steel, and so on until the file proves to be powerless for abrasion. Cohesion may be further illustrated by the force which is necessary to tear an iron bar or a thread asunder. The force required to separate the parts varies; and is not in all cases the same for two different pieces of iron, for the cohesive force in metals may be considerably increased by hammering, rolling, or drawing.

Compressibility is a quality in virtue of which solid bodies and gases may be reduced in size or volume. The compressibility of liquids is so small as to be considered insignificant; but, as a matter of fact, liquids may be compressed under enormous pressure, though very slightly indeed. The compression of iron, or of copper, under the hammer is effected solely by pressing the particles forming the body closer together. In a solid body these molecules arrange themselves as crystals, which may easily be observed by snapping a

piece of iron short asunder. These crystals of course have angles, and they are piled against each other, forming interstices between them. As the hammer comes down, the crystals are broken and driven more and more closely together. Hence the reduction in the bulk of the metal under such treatment.

Air, steam, and all other gases are compressible; and may under pressure be much reduced in bulk.

Elasticity is a property in bodies the very opposite of compressibility, and it differs in intensity in different bodies.

Many solids subjected to pressure do not alter their shape in the least when the pressure is removed. Such stolidity is far from being the case with both water and gas. Water is eminently elastic, as was proved by a celebrated experiment in which water enclosed in a strong cannon was subjected to a high pressure of 15,000 lbs. per square inch; on the pressure being suddenly withdrawn, the cannon burst:—not burst under pressure, but actually after the pressure was removed, by the action of the water in resuming its original volume.

All gaseous bodies are elastic. Suppose we take a vessel and half fill it with water or wine. There it is. We can see it is half full, and further we can make a statement and say it is, for instance, a gallon bottle, and being half full it must contain two quarts. Very true. Now we cannot do this with a gas. It is impossible to half fill a bottle with air or steam.

Elasticity is powerfully manifested by twisting a suspended cord with a weight on the end of it. We may twist it, say, to two dozen turns by hand, and when it is allowed to untwist, it will not only untwist itself

twenty-four turns, but more times. The explanation of the circumstance of a cord untwining itself more times than are required for resuming its normal condition, is to be found in the fact that the molecules of the cord are not round. If they were round, in any body, there would be no such thing as elasticity by means of torsion, and from the fact of the molecules of the cord being angular, they are bound by the laws of nature, after being disarranged, to go back again into exactly their old position, and it is simply a manifestation of this desire and energy to recover their appointed places that carries them beyond their natural arrangement.

If these molecules were round, they would roll round each other. To illustrate how the particles of matter persist in holding their places—their appointed places—we will mention that a crooked bar of iron made straight by a succession of light blows will, after the scale is taken off by a turning-tool in a lathe, resume its crooked form. Shafting for a factory is seen crooked like this after leaving the lathe.

Again, when a child throws a ball upon the ground to cause it to bounce upwards into his hand, he accomplishes his self-imposed task and amuses himself solely because the molecules composing the ball, which were compressed in the fall, instantly rearrange themselves by the rebound.

Dilatation.—When matter in either of its three states, as a solid, a liquid, or a gas—and it is worth noting there are but three—is extended by any physical agency, such as heat, and not by human power, the process is called dilatation. The metals upon the railway are expanded by the physical agency of the sun's heat. In the thermometer, the dilatation of a liquid

—mercury—is employed to measure degrees of heat. Dilatation in conjunction with contraction in metal was well employed by M. Morin to straighten some walls in the Conservatoire des Arts et Métiers, where the weight of the roof had caused the walls to bulge outward. M. Morin fixed some strong bars of iron inside the building, reaching from the wall on one side over to the wall on the other side. Each end of each bar was screwed and extended through the wall of the building to the outside, and held by a large nut. The nuts were tightened after the bars were heated and expanded, and the contraction of the iron in cooling, shortening the length of the bar, drew the two walls nearer together. The process was repeated until the walls were restored to the upright position.

Here is a fine illustration of a sensible man, thrown on his own resources, calling to his aid a simple law of nature.

Density.—Having made the foregoing general observations of the nature and properties of solids, liquids, and gases, it may be added that some bodies are endowed with special properties, unlike others; and, again, some bodies have properties common to all, and yet have some special property of their own.

Iron is hard, glass is hard, yet one is flexible and the other is brittle.

Iron is hard, and steel is harder, but for many purposes iron is the more suitable metal, simply because iron has the property of ductility in a greater degree than steel, and is not so liable as steel is to be bent beyond the limits of perfect recovery.

All bodies have their densities, but the property of density is one of degree, and is regulated by the

number of molecules in the body, by their proximity to each other, and by the quantity of matter in each particle.

The term density is purely relative. If a body contains more matter than another, both having the same bulk, the one is said to be denser than the other, in proportion to the relative quantities of matter they contain. Or, if the one body contains the same quantity of matter as the other, but in a less volume, its density is said to be greater, in proportion as its bulk is less than that of the other. Hence the density is inversely proportional to the volume under which it is contained.

The relative quantities of matter in bodies are known by their gravity, or weight. According to Sir Isaac Newton, the original particles of matter being equal, and consequently endowed with equal gravity, bodies or assemblages of particles will have a gravity proportionate to the number of particles contained in them.

Observe: whenever a body, mass, or quantity of matter is spoken of, its weight or gravity is always understood, that being the proper measure of the quantity of matter.

The density of bodies may be found by weighing equal bulks of each. By this process solids must be previously reduced to the same shape or size, and in the case of fluids the same vessel must be filled with them, and be weighed separately.

It is impossible to say that a body is dense without reference to some standard; and, by common consent and practice, the standard of comparison is pure water. A cubic foot of pure water weighs nearly 1,000 ounces, avoirdupois. Assuming 1,000 to be the specific

density of pure water, and comparing all other bodies with it, their several densities are easily obtainable. Water being 1,000, cast-iron is 7·217, or more than seven times as heavy, bulk for bulk.

Malleability is a special property of great importance in the engineering world. It employs the labour of thousands of men. What should we do if it were impossible to make thin plates of iron? As it is, we can, by virtue of this property, build bridges and construct buildings—the Menai Bridge and the Crystal Palace, for instance—that we can look up to and enjoy. Now if everything were, say, of the nature of wood, we should no doubt have something to admire, but we should have no steam-engines. Very well; malleability is a quality that can be regulated, modified, or intensified as it suits the craftsman. Steel rails, for instance, hot from the rollers, are allowed to cool gradually, and a satisfactory result is attained. They will bend, and not snap, when loaded with the weight of a train; but were the hot rail to be plunged into cold water, it would still be malleable, but it would be highly sensitive and liable to break if surprised by a sudden pressure.

Hardness.—There is here a special feature. Hardness differs from density. Take a cubic inch of iron, and a cubic inch of glass, and we shall find—what most people expect to find—that the iron is the heavier; but notwithstanding that density is in its favour, the glass will scratch the iron, and the iron will not scratch the glass.

Summary: a body—iron—may be dense and not hard, and a body—glass—may be hard, very hard, and not dense. Explanation: The molecules composing iron

and glass are definite and susceptible to change; but, in forming masses, there is a difference in the angle of contact, which in the case of glass gives it a mechanical advantage.

Once more: the properties of metals are wonderfully modified by combinations of metals, or alloys.

In the axle-boxes of railway carriages and engines, alloys of copper, zinc, tin, and lead are employed for the bearings. Brass, which is an alloy of copper and zinc, if used without tin and lead in intermixture, will not do. All tin, no brass and no lead, would be quite as bad; lead only would be still worse. There is a mixture of the elements in such proportions as experience has taught the brass-founder are best; neither too hard nor too soft. The composition of the alloys in church-bells and tower-bells, that have a beautiful musical sound, is the result of much patient investigation.

SUBJECT 2.—EXPANSION AND CONTRACTION. *Expansion* is a characteristic of all bodies:—solids, iron:—fluids, water:—gases, air. It is caused by the application of heat. If zinc, lead, tin, copper, and iron were submitted to tests, the zinc would first expand, then lead, then the tin, next the copper, and lastly the iron. The expansion of bodies by heat is the result of the vibration of the particles or molecules of the material, slightly separating them. That it is so, may be proved by increasing the heat, and thus increasing the vibrations until the particles separate altogether, and the body or mass operated upon is resolved into a liquid. The melting of iron is an instance in point.

The expansion of bodies by heat is a fact of the highest importance. Without expansion and solution

of heat, we could not manufacture the articles we do in the arts, nor should we be able to raise steam, for steam may even be called melted water. The amount of expansion for equal degrees of heat is different in different bodies. If it were not so, then tin would expand at the same rate as iron. The copper fire-box expands before the iron shell does; and the excess of expansion is one of the causes of a fire-box cracking. Fire-boxes are not generally cracked in the cooling, the cracks occur during the heating. On this account, boilers should not be urged by steam-blowers. These blowers should be pitched out of the steam-shed, having ruined many fire-boxes. The force with which bodies expand is the supreme force in nature. It overcomes every resistance, and cannot be opposed. It is very great in locomotive boilers, and means have been provided, in the holes in the expansion-brackets, to make allowance for expansion. It may be observed by comparing the position of a boiler on the frame when cold, with its altered position when hot.

In early practice, the expansion of boilers by heat was not provided for in the construction of the locomotive, and the result was that inconvenience was caused by boilers working loose in the frames. Studs, holding what were called expansion-brackets, have been blown out of the boiler, and have delayed trains. These were not really expansion-brackets, but struts. It is a fact that all bodies are expanded by heat, varying considerably in extent. But all gases expand equally. Permanently elastic fluids are capable of expanding indefinitely, without the application of heat. If a gas be placed in a vessel, having a capacity of one cubic foot, and if it be enlarged to one foot and a half without

interfering with the gas, the gas would expand, and would continue to fill the vessel.

Water is seen to expand in the boiler. When a boiler has been washed out, and filled again half full of water, on the application of heat the water will rise in the gauge-glass. Heated tyres, heated bearings, and heated water, are all instances of expansion by heat.

Every solid thing in the world may be expanded by heat, and at a greater or less temperature liquefied or melted, and ultimately, by an additional accession of heat, vaporized as water is. There is every reason to believe that this earth was at one time in a liquid state.

Contraction is the reverse of expansion, and it is also a power in nature. It is generally produced by the abstraction of heat, allowing the particles composing the body to rest.

This well-known property is invariably made use of in fitting tyres upon wheels. The tyres are expanded in a furnace, and so enlarged that they can be placed over the rims of the wheels which they fit, and which were too large to receive the tyres when cold. The tyres, having been placed on the wheels, are allowed to cool, when they grip the wheels with enormous force.

It is by the force of contraction that tyres of wheels are caused to burst in winter.

There is an exception in the case of water. When it is cooled down to the freezing-point, it increases in bulk as it freezes, and exerts a prodigious expansive force, which is proved when it freezes within the feed-pipes of a locomotive engine and bursts them. This strange exceptional circumstance is caused by the particles of water assuming a crystalline form.

SUBJECT 3.—AIR AND WATER. *Air* is an invisible elastic body, and has weight. It is composed of two gases, oxygen and nitrogen. The latter by diluting the oxygen enables us to breathe the air. A very slight alteration in the proportion of the mixture would extinguish life.

That the mixture does vary is a fact, and where there is more nitrogen than oxygen it is favourable to our constitution. The reduced mixture is found to be of practical importance to invalids, who visit such places as Eastbourne and Hastings for the benefit of the air. Galileo taught that air had weight, and Torricelli found that it had pressure. These discoveries were made about the seventeenth century. They were corroborated by exact experiments; and it was proved that the pressure of the atmosphere was equal to the pressure of a column of mercury thirty inches high.

In virtue of the difference between the weights of mercury and water, the latter will rise in a perfect vacuum 34 feet, by the pressure of the air on the exposed surface of the water.

That is, if a tube 34 feet high, be closed at one end, and the air be drawn from the inside, and the open end at once dipped into water before any air re-entered it, the water would rise in the tube to the top. An ordinary pump with good clacks will draw water close on 28 feet.

Dr. Priestley, one day dining in company, being struck with the effluvia of the victuals, took the opportunity of examining the air of the room, and found it badly ventilated.

The means he used to secure a sample was very striking, and serves to illustrate the gravitation and

elasticity of the air, and reveals its real nature as an active power in nature.

He went to a sideboard where there were two decanters partly filled with water; he poured the water from one decanter into the other, and without any ceremony put the stopper into the empty decanter, and left the room for his laboratory.

He knew that as the water was poured out of the decanter it would be filled with air simultaneously, and that if he had left the decanter five minutes or five hours there would have been no more air in it than there was in it already.

Water is a transparent fluid without colour, smell, or taste. It is composed of oxygen and hydrogen. If the hydrogen be withdrawn, the oxygen which is left is the principal supporter of life. Hydrogen stands first for heating-power, as a combustible element of coal. Three-fourths of the surface of the globe are covered with water. Water becomes solid at 32° Fahr., and at 212° Fahr. it becomes a vapour—steam. It enters into the composition of all animal and vegetable bodies, and both man and beast can go longer without food than without water. It is capable of dissolving a greater number of natural bodies than any other fluid whatever, and especially saline bodies. Hence, water is chalky in one district, and sandy in another. It exists in three forms or states:—solid, as ice; liquid, as water; and vaporous, as steam.

The expansive force of water is very great, as is well exemplified in the bursting of water-pipes, in which the water is frozen, and also as a gas—as steam.

In the liquid form, water is incompressible, and is used with machinery for shunting trucks in the

goods yard of the Dundee Station of the North British Railway.

By calculating the weight of water raised into a vacuum-tube in the manner already described, philosophers found it would require a pressure of 14·75 lbs. ($14\frac{3}{4}$ lbs.) to the square inch to do it, and therefore the pressure of the atmosphere is stated to be, in round numbers, 15 lbs. per square inch.

By neglecting the pressure of the atmosphere, many disasters have occurred. Air is as much a substance as anything else in nature.

In the turned joints of metals many misfits have been made in consequence of the elastic property of air not being properly recognised. Piston-rod ends and pump-rams fitting into cross-heads have, in an incredibly short period of time, worked loose by air lodged and compressed in the bottom of the hole in the cross-head.

N.B.—Having attended to the investigation of the general properties of matter, such knowledge cannot fail to help in our future progress, and therefore we have been most profitably employed.

But what have we learned? Why, that there is a marvellous consistency of purpose, of intelligence, of contrivance, of unerring truth—that every particle of matter is bright in its humble sphere, invested with provisional powers having uniform effects. If any one doubts this let him follow on. Before us is a simple undecomposed substance—iron—found chiefly in the northern regions of the earth. The iron of commerce is obtained by chemical means, by means of known and fixed appliances. Vulcan erects an oven or a cupola, and bakes the iron ore; which operation dissipates volatile matter with which the ore is in its natural

state combined. Result: a lava. Vulcan breaks this into convenient pieces, and introduces them into a better furnace, with fluxes to deprive the lava of its iron. That done, the result is "pig"-iron. Vulcan, with experience and great practical skill, breaks up these "pigs" and bakes them, driving off the carbon, and the yield is a better iron. Vulcan puddles the iron upon the hearth, and brings it "to nature" from the state of crude iron to a pure, to a purer, and a purer still condition, until good steel is produced. One acquires a strong impression of the constancy of nature's laws, from the absence of all uncertainty in the results to be obtained from the same course of treatment. The laws of nature, and the properties and the power of bodies and their reactions upon each other, are ever the same. The study of natural philosophy proceeds on a fixed basis of truth, and to find new truth is the highest employment of the human brain. Sir Isaac Newton has laid down four rules for the guidance of inquirers, evident to the senses, in their investigations respecting the several parts of the grand machinery and agency of nature, to make the truth self-evident. He states: 1st. More causes of natural things are not to be admitted than are both true and sufficient to explain the phenomena. 2nd. And therefore of natural effects of the same kind, the same causes are to be assigned, as far as it can be done, as light in a fire and the sun, reflection of light in the earth and in the plants. 3rd. The qualities of natural bodies, which cannot be increased or diminished, and agree to all bodies in which experiments can be made, are to be reckoned as the qualities of all bodies whatever: thus because extension, divisibility, hardness,

mobility, impenetrability, and gravity are found in all bodies which fall under our cognizance or inspection, we may justly conclude they belong to all bodies whatsoever, and are therefore to be esteemed the universal properties of all natural bodies. 4th. In natural philosophy, propositions collected from the phenomena by induction are to be deemed—notwithstanding contrary hypotheses—either exactly or very nearly true, till other phenomena occur by which they may be rendered either more accurate or liable to exception. This ought to be done, lest arguments of induction should be destroyed by hypothesis.

SUBJECT 4.—GEOMETRY. This is a branch of mathematical science, and it is an alphabet relating to form, extension, and magnitude of bodies, and used daily in general workmanship between one man and another. It is a scheme to classify different forms and call them by different names; so that to attain to a knowledge of this alphabet is in every respect similar to the attainment of the alphabet of letters, namely, by acts of study until we are sufficiently acquainted to distinguish one form, or one letter, from another. In degree this science holds a very high position in mechanical constructions under the title of practical geometry, and the following is a selected portion that is usually employed in conjunction with the square and compasses.

A point (.) has position, but not magnitude.

A line —— has length, but not breadth or thickness.

A right line is a straight line.

A curve line changes its direction from point to point.

Parallel straight lines are a number of lines separate from each other, such that, if prolonged in either direction, they would never join: thus—(Fig. 20.)

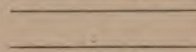


Fig. 20.

A vertical line stands at right angles to the surface of the earth. It is a plumb-line. An engine bracketed to a wall is called a vertical engine—not a perpendicular engine. A B is the surface of the earth, or floor, C D is the vertical line. (Fig. 21.)

Fig. 21.

A perpendicular line is one that stands perpendicular to another line, in whatever position that line may be. It is not necessarily a plumb-line. (Fig. 21.)

An angle is a space between two lines which start from a point, the vertex—or it is a corner A. (Fig. 22.)

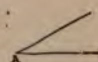


Fig. 22.

A right angle equals 90°, A C D. (Fig. 21.)

An obtuse angle is greater than a right angle. (Fig. 23.)

An acute angle is less than a right angle. (Fig. 24.)

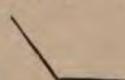


Fig. 23.

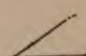


Fig. 24.

Triangles are three-sided figures which differ according to the comparative lengths of their sides. They group angles into figures, thus:—

A right-angled triangle is a figure which has one right angle in it, A B C. (Fig. 25.) The line from point A to point C converts Fig. 21 from a right angle into a right-angled triangle.

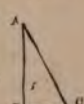


Fig. 25.

An acute-angled triangle is a figure which has all its three angles acute: the line from point *e* to point *d* converting Fig. 24 from an acute angle into an acute-angled triangle. (Fig. 26.)

Fig. 26.

P

An obtuse-angled triangle is a figure having one obtuse angle in it; the line from point *e* to point *c* transforming Fig. 23 from an obtuse angle into an obtuse-angled triangle. (Fig. 27.)


Fig. 27.

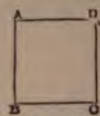


Fig. 28.

A square is a figure whose sides are all equal to each other, containing four right angles A B C D. (Fig. 28.)

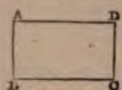


Fig. 29.

A rectangle is a figure of which the opposite sides are equal, and the ends equal, and the angles all right angles. (Fig. 29.)

A rhombus is a figure of which the opposite sides are parallel, and all the sides equal to each other, but the angles not right angles.

A circle is a curve extended by the compasses until the line returns into itself again. The line B A D is called the circumference; the middle, E, the centre. The radius E A is the line extending from the centre, E, to the circumference, A; it is the opening of the compasses when drawing the circle. (Fig. 30.)


Fig. 30.


Fig. 31.

The diameter of a circle is the distance from circumference to circumference, through the centre. When a big-end is gauged with callipers, the diameter is given. (Fig. 30.)

A segment of a circle is a part of a circle, G H I. It may equal a semicircle. (Fig. 31.)

A straight line drawn across a part of a circle is called a chord; A D (Fig. 30).

A tangent to a circle is a straight line drawn so as just to touch the circle without cutting it.

The rail is a tangent to the wheel of an engine; and the point where they touch each other is the point of contact.

A sector of a circle is a space bounded by two radii and comprehended by an arc, A E D, Fig. 30.

The radii are the two lines extending from a point at the centre to the circumference, and the arc is the curve between the two points.

The circumference of a circle is, for the purpose of trigonometrical calculations, divided into 360 parts; and each part is called a degree. Each degree is also divisible into 60 parts; each of these parts is called a minute.

Each minute is divisible into sixty parts, called seconds. Degrees, minutes, and seconds are symbolised thus:—

Degrees $^\circ$, minutes $'$, seconds $''$. Read, for instance, 25 degrees, 15 minutes, 10 seconds $= 25^\circ\, 15'\, 10''$.

SUBJECT 5.—MECHANICAL DRAWING. There are standard works published which teach the art of drawing, and no doubt the statement itself will be sufficient to induce many to obtain them, and to place themselves under a course of training. But the most important point is, in all things, to make a beginning; once started a great achievement has been accomplished. When Franklin made his discovery of the identity of lightning and electricity, people of the baser sort asked with a sneer, "Of what use is it?" The philosopher's retort was: "What is the use of a child? It may become a man!"

The following are a few of the simplest and most ordinary problems of drawing, which may be taken as examples for exercise, and introductory to an art of

much importance to those who have charge of the construction or the management of steam-engines.*

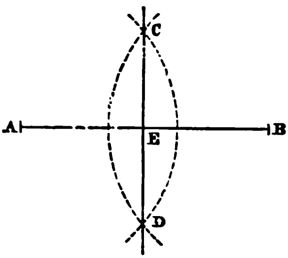


Fig. 32.

To bisect (or divide into two equal parts) a given straight line by a line drawn perpendicular to it.†

Let A B (Fig. 32) be the given straight line. 1. Set one foot of the compasses on the extremity A, as a centre; and with any convenient radius that is evidently greater than half the line, describe the arc C D; similarly from the point B, as a centre, describe another arc with the same radius, cutting the first one at the points C and D.

2. Through the points of intersection C and D draw a straight line C E D, this line will divide the given line A B into two equal parts, A E, E B, at the point E, and will also be a perpendicular to the line. It is not necessary in practice to draw the complete arcs. An experienced eye can readily anticipate the points of intersection of the arcs within small limits. Neither is it necessary to do more than apply a straight-edge to these points of intersection, and tick the point E, unless, indeed, the perpendicular itself be wanted, which is often the case.

The same process serves for the bisection of a circu-

* From "The Workman's Manual of Engineering Drawing," by John Maxton.

† In presenting methods of performing geometrical operations, the T-square, parallel rulers, &c., will, where applicable, assist considerably on many occasions in simplifying the solution of the problems, and with an accuracy generally quite sufficient for practical purposes.

lar arc; for, supposing A B to be the chord of the arc, the perpendicular which bisects the chord will also bisect the arc.

To draw a perpendicular to a given straight line from a given point in that line.

FIRST, When the point is near the middle of the line.

1. Let A B, Fig 33, be the line, and C the point near the middle from which the perpendicular is to be drawn. On C as a centre, with any convenient radius, set off equal parts, C D and C E, on the line A B.

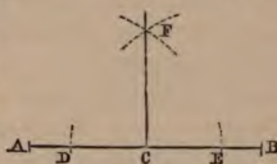


Fig. 33.

2. On D and E as centres, with a greater radius, describe equal arcs intersecting at F, and, if wanted, on the other side of the line also.

3. Draw the line F C—it will be a perpendicular to the line A B at the given point C.

SECOND, When the point is at or near the extremity of the line.

1. Take any convenient point C, Fig. 34, obviously within the perpendicular to be drawn from the given point B, place one foot of compasses on C, and extending the other to B, describe a circle A B D cutting the line A B at A.

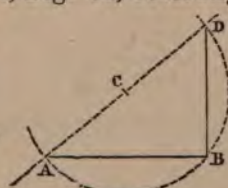


Fig. 34.

2. Set a straight-edge to the points A and C, and draw a line cutting the circle at D.

3. Draw D B, which will be the perpendicular required.

Another method:—1. From the given point B set

off on the given line a distance such as B A, equal to three of any units of measure, as 3 inches or 3 feet.

2. From B as a centre, with a radius of four of the same parts, describe an arc supposed to pass through D.

3. From A as a centre, with a radius of five parts, describe an arc cutting the other arc at D.

4. Draw D B for the perpendicular required.

This last method of solving the problem can be easily applied on a large scale for laying down perpendiculars on the ground. The numbers 3, 4, and 5 are, it is to be observed, taken to measure respectively the base, the perpendicular, and the hypotenuse of the right-angled triangle A B D. Any multiples of these numbers may be used with equal propriety, when convenient; as 6, 8, and 10, or 9, 12, and 15, whether inches, feet, or any other units of length.

To draw a perpendicular to a given line from a given point without the line.

First, When the point is conveniently near the middle of the line.

1. Let A B, Fig. 35, be the line, and C the point without it. On C as a centre, with a convenient radius, describe an arc cutting the line A B at the points D E.

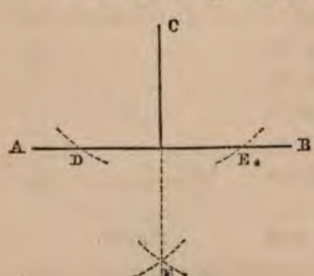


Fig. 35.

2. On the points D E as centres, and with equal radii, describe the arcs intersecting at F.

3. Set a straight-edge to the points C and F, and draw a straight line from C to the line A B. This will be the perpendicular required.

If there be no room below the line A B the intersections F may be taken above, that is, between the point C and the line. This mode is not, however, so good as the one already described, because it is not likely to be so exact.

SECOND, When the point is near the end of the line.

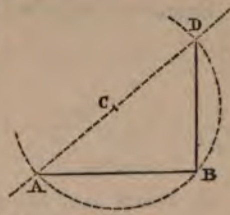


Fig. 36.

1. Let D, Fig. 36. be the given point, and A B the straight line. From D draw any straight line, D A, meeting A B at A.

2. Bisect A D at C, and on C as a centre, with C A as a radius, describe an arc cutting A B at B.

3. Draw D B for the perpendicular required.

To describe a square on a given straight line.

1. Let A B, Fig. 37, be the straight line, or the base of the proposed square. Draw A C and B D perpendicular to the base, from its extremities, and make each of them equal to A B.

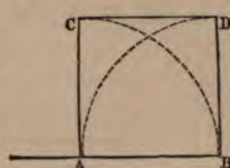


Fig. 37.

2. Draw the line C D; this will complete the square A B C D on the line A B.

To draw a line parallel to a given line.

FIRST, To draw the parallel at a given distance.

1. Let A B, Fig. 38, be the given line. Open the legs of the compasses to the required distance, and from any two points C and D (the farther apart the better) describe two circular arcs on the side towards which the parallel is to be drawn.

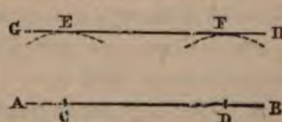


Fig. 38.

2. Apply a straight-edge tangentially to the arcs at

E and F, and draw the straight line G H; this will be a parallel to the given line.

SECOND. To draw the parallel through a given point.

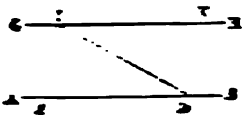


Fig. 39.

1. Let C, Fig. 39, be the point: from C draw any line C D to A B.

2. From C and D as centres, describe arcs D E and C F.

3. Make D E equal to C F, and through the points C E draw the parallel G H. This is the line required.

The methods of describing squares and rectangles already given are also available for drawing parallels, though they are not so generally ready of application as the foregoing.

To divide a straight line into any number of equal parts.

1. Let A B, Fig. 40, be the straight line, to be

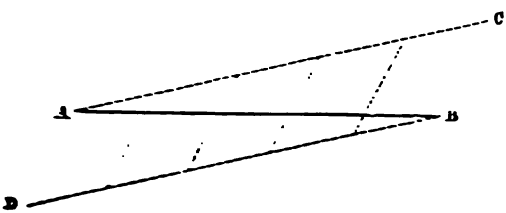


Fig. 40.

divided into, say, five equal parts. Through the points A and B draw two parallels A C, B D, forming any convenient angle with A B.

2. Take any convenient distance, and lay it off four times (one less than the number of parts required) along the lines A C and B D, from the points A and B respectively, and join the first on A C to the fourth on B D, the second on A C to the third on B D, and so on.

The lines so drawn will divide A B into the required number of equal parts.

With the assistance of the straight-edge and the set square this process may be considerably expedited. Thus, having drawn an oblique line C B, Fig. 41, from the point B, lay off five equal parts on it; set the edge of the square E to the point A, and the fifth division on C B; slide the square parallel to itself on the straight-edge F, in the direction A D, and draw parallels from the points of division on C B to the line A B. The latter will thus be divided into five equal parts.

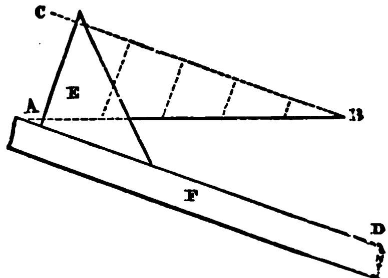


Fig. 41.

To construct an equilateral triangle.

1. Let A B, Fig. 42, be the length of the side of the triangle. On A and B as centres, with radius A B, describe arcs cutting each other at C.

2. Join A C and B C; the triangle, A B C, thus formed is equilateral.

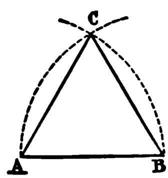


Fig. 42.

To construct a triangle, having its three sides of given lengths.

1. Let A B, Fig. 43, equal the base of the triangle.

On A as a centre, with a radius equal to one of the sides, describe an arc.

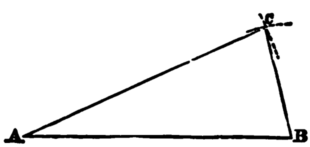


Fig. 43.

2. On B as a centre, with a radius equal to

the third side, describe an arc cutting the former at C.

3. Join A C and B C. The triangle is thus completed as required.

To draw a straight line, so as to form any required angle with another straight line.

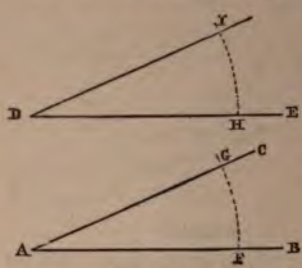


Fig. 44.

1. Let B A C, Fig. 44, be the given angle, and D E the line upon which an equal angle is to be drawn at the point D.

From the points A and D, with any convenient radius, describe arcs F G and H I.

2. Set off the length of the arc F G, contained between the lines A B and A C, upon the arc H I, and draw D I. The angle E D I will be equal to the given angle B A C.

Longitudinal sectional elevations (or objects cut through lengthways vertically), longitudinal sectional plans (or objects cut through lengthways horizontally), and transverse sections (or objects cut through across vertically), are necessary drawings at all times, and to get measurements from the actual engine to make such drawings is often an impossibility, however essential it is to show internal arrangements, often made in the casting of a piece of machinery, and never seen again unless broken up. There is often no other way of showing the thickness of material than a section. If the object in question is in process of construction in the factory, the only resort for what is required for the purpose is the large original working drawings which show the structure of the interior parts.

In drawings of machinery it is usual to place the plan above the side elevation, and central on the paper if possible. End elevations or sections should be to the right and left of the principal elevation, and adjoining the end of the elevation which they severally represent.

When only one view of a steam-engine has to be made, the side elevation (or view showing the crank

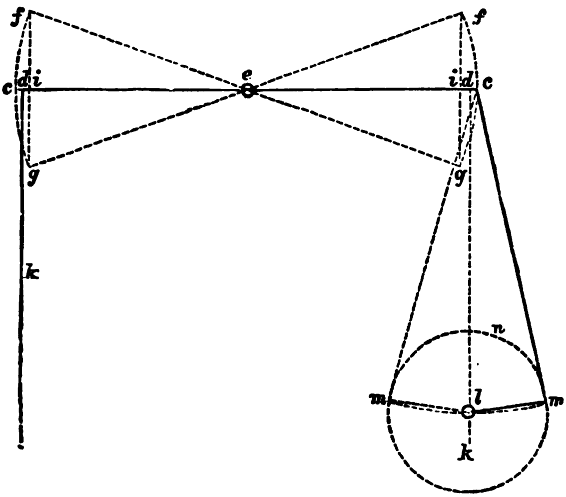


Fig. 45.

breadth) is the most likely to explain on what principle it is constructed. The side elevation of most machinery, other than the steam-engine, would generally give the best idea of the construction, when only one view is to be shown.

If two views are to be shown of the same machine, with the working parts in a different position, having once got the centre lines in each view, one measure-

ment by compasses should be applied to the corresponding part in each of such views, and thus save time by not doing the same thing twice over.

To find the centre line of cylinder and fly-wheel shaft in a beam engine.

Let the horizontal line *c e c*, Fig. 45, be the centre line of beam or lever when at half stroke, and *e* the centre. With the half length of beam *e c*, and from *e* as a centre, describe the radius *f c g* at each end, as shown; set off the extremities of the stroke or *vibration* of beam at *f* and *g*, a half on each side of centre line *c e c*, and join *f g* by a vertical line, intersecting the horizontal line *c e c* at *i;* bisect *c i* at *d*, and through the point *d* draw the vertical line *d k*, which will be the centre lines of cylinder and crank shaft.* To find the position of crank at half stroke. With half stroke (or distance *i f*) as a radius, and on the line *d k*, from *l* as a centre, describe the circle *n*—indicating the path of crank. The length of the connecting-rod is taken from the point *c* to the centre of shaft *l*. With the radius *c l* describe the arc *l m*, cutting the circle *n* at *m*, and join *l m* by a straight line, which will be the centre line of crank at either side of the shaft, when the lever is at half stroke.

The figures annexed are not intended for any other purpose than to introduce the use of the square and compasses. Figs. 46 to 54, and 58 to 60, are borrowed from "A Rudimentary Treatise on the Locomotive Engine," by Dempsey and Clark; and Figs. 49 to 51, 55 to 57, and 61, are borrowed from "Locomotive-Engine Driving," by the author.

* The centre of shaft is sometimes placed vertically under the end *c* of lever.

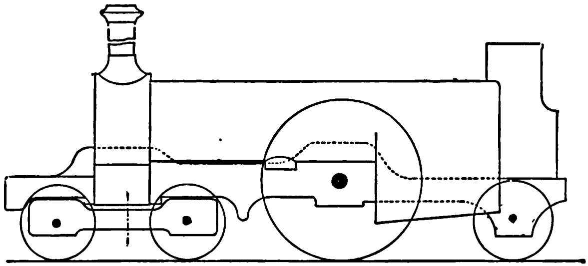


Fig. 46.—Stirling's Express Engine, Great Northern Railway.

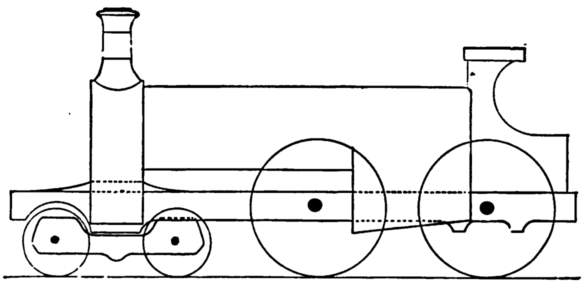


Fig. 47.—Johnson's Express Engine.

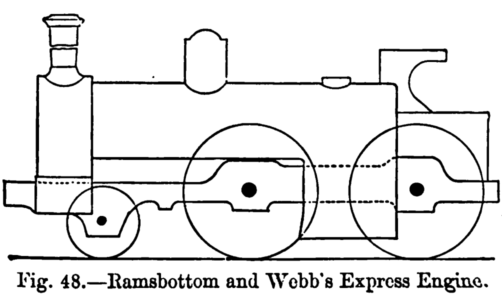


Fig. 48.—Ramsbottom and Webb's Express Engine.

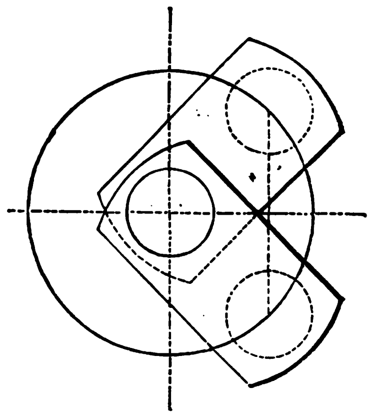


Fig. 49.—Position of the Cranks for testing the Valves and Pistons.

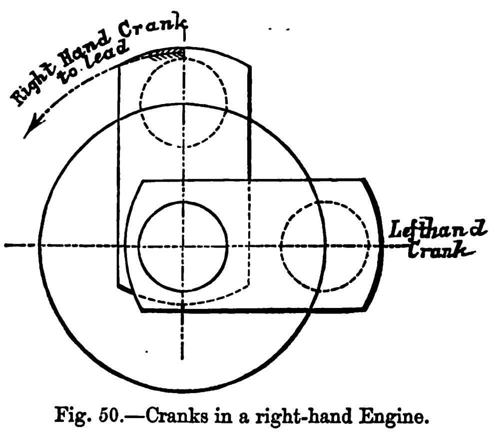


Fig. 50.—Cranks in a right-hand Engine.

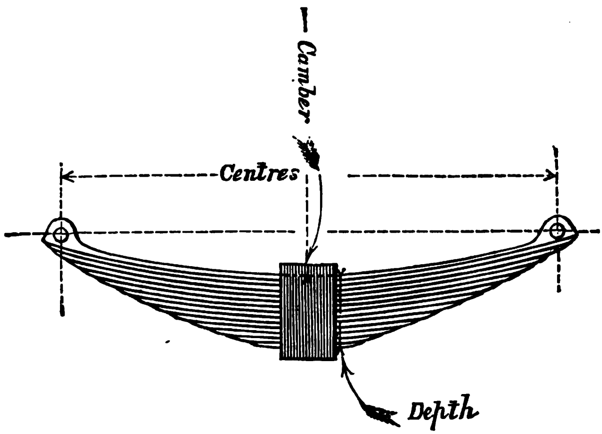


Fig. 51.—Laminated Bearing-spring.

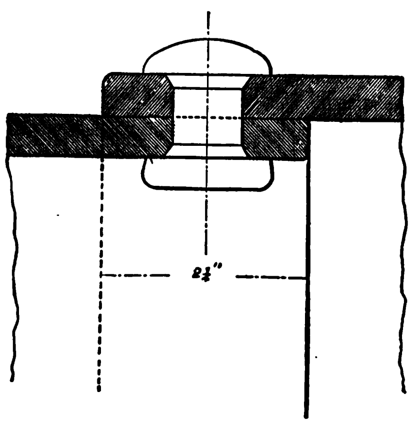


Fig. 52.—Single-riveted Lap-joint of Boiler-plates.

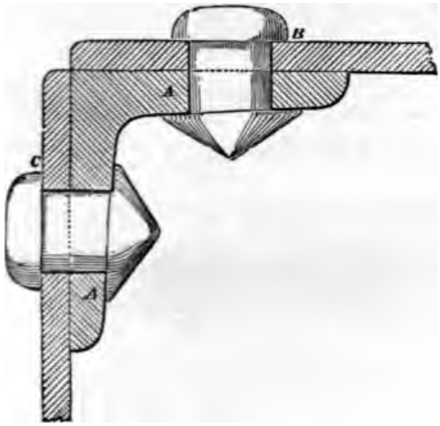


Fig. 53.—Section at junction of boiler and fire-box shell, lower side. ½ size. *A*, angle-iron; *B*, lower plate of barrel; *C*, front plate of fire-box shell.

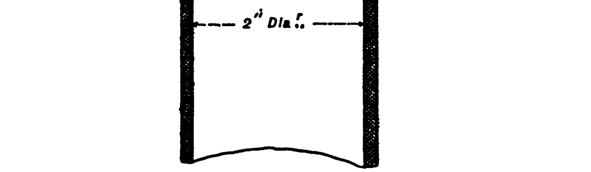


Fig. 54.—Fixing of Flue-tube into Fire-box Plate.

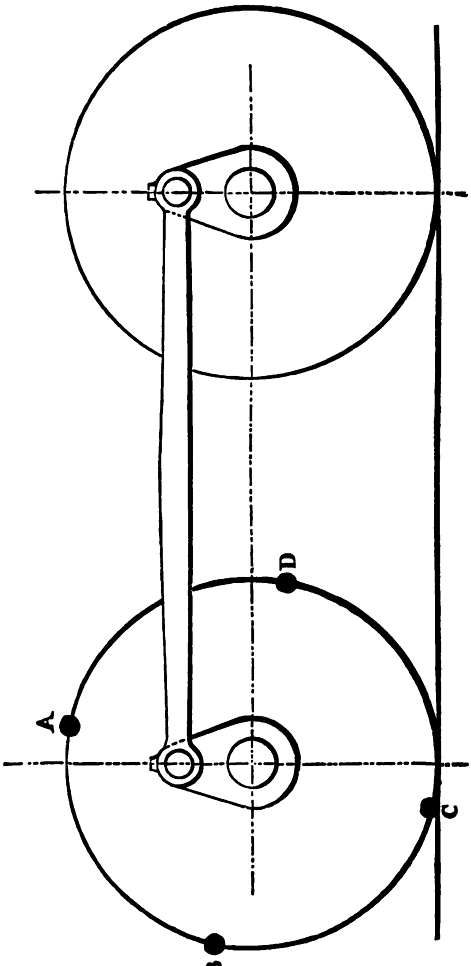


Fig. 55.—To mark the Beats of an Engine.

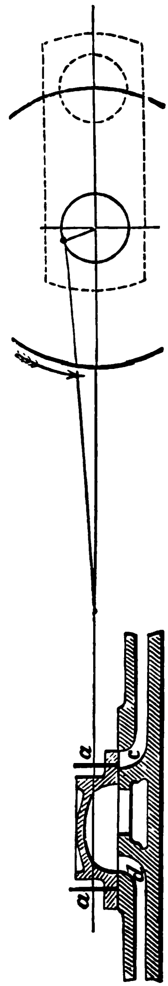


Fig. 56.—Modern Slide-valve.

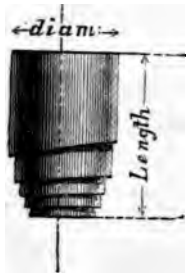


Fig. 57.—Conical Bearing-spring.

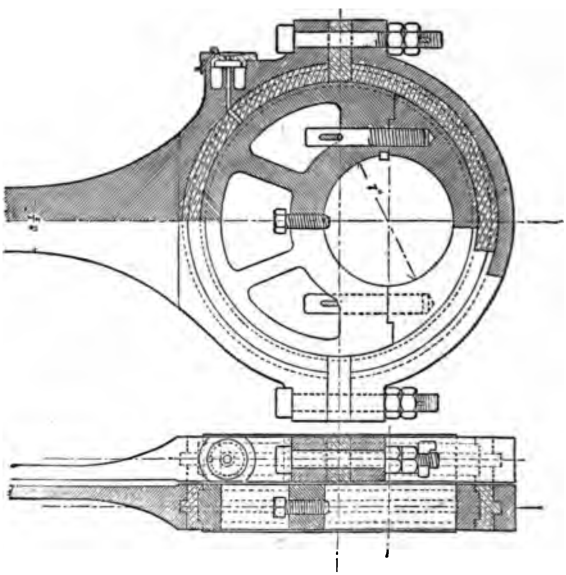
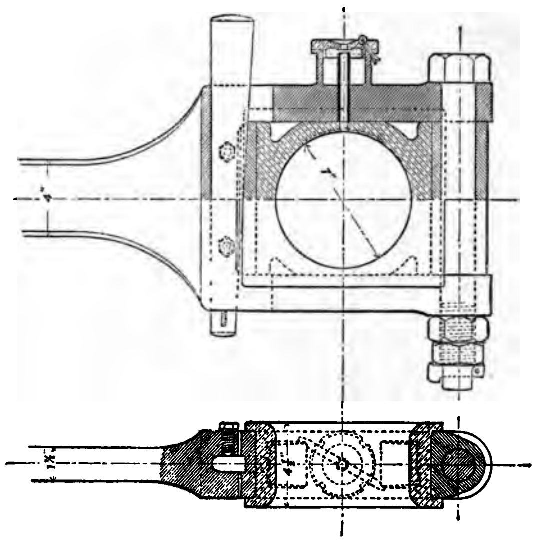


Fig. 58.—Excentric and Rod.



Figs. 59.—Connecting-rod.—Large End.

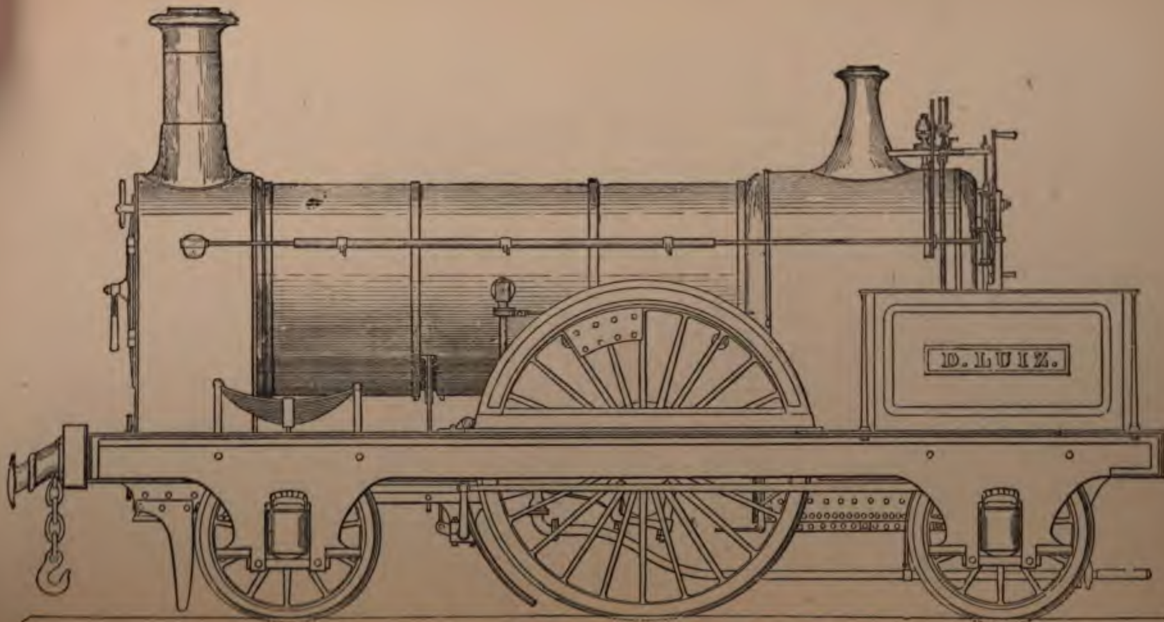


Fig. 60.—Express Passenger Locomotive, constructed by Messrs. Beyer, Peacock, and Co.

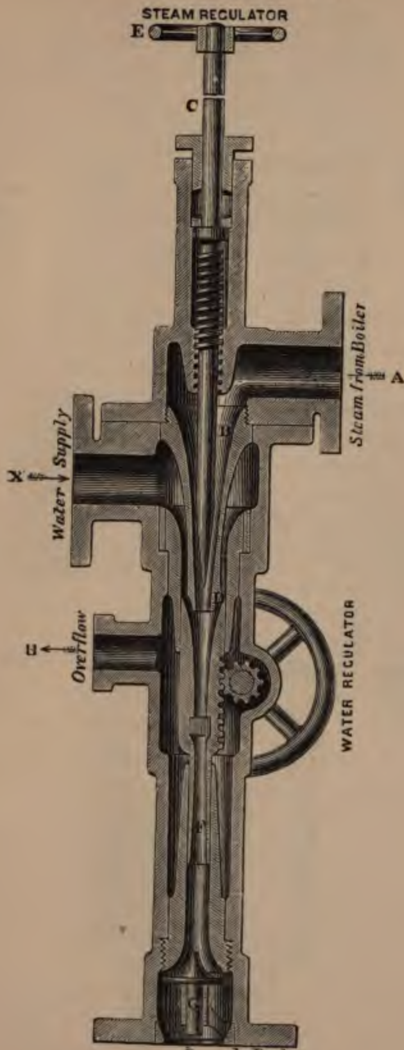


Fig. 61.—Injector.

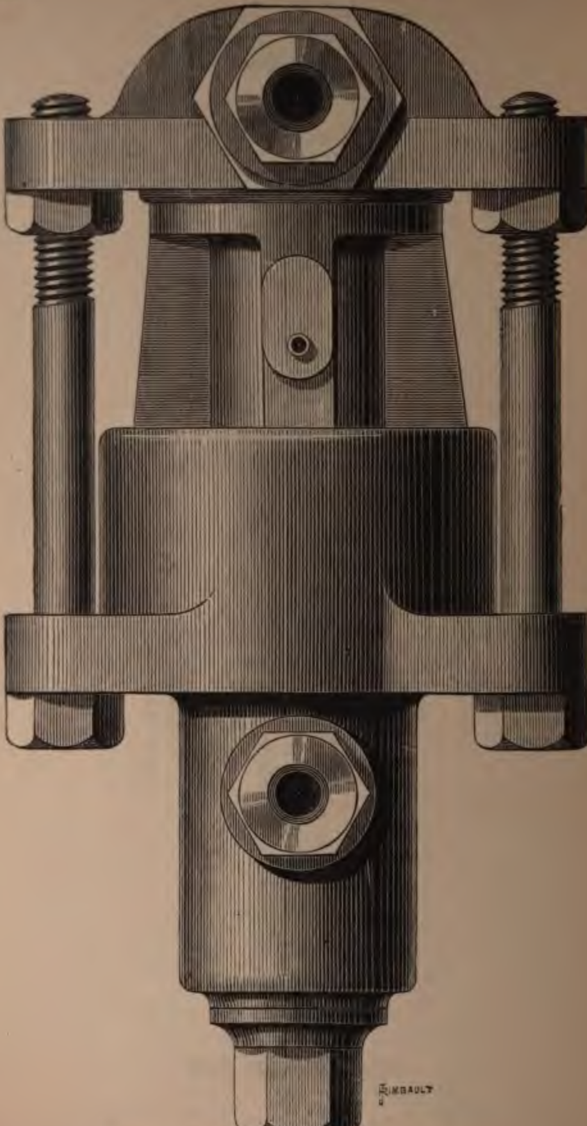


Fig. 62.—Triple Valve, Westinghouse Brake.

APPENDIX.

CONTINUOUS BRAKES.

PUBLIC opinion is so far matured on the question of the braking-power of trains, that it is now agreed, by common consent, that the power of quickly arresting the motion of a train is just as needful as the power of quickly setting it in motion. The recommendation of the Railway Accidents Commission, after having heard the best evidence on the subject, has been in favour of a continuous and automatic brake, which should act instantaneously on the application of power for stopping a train, and which should also act instantaneously on each part of a train, in case it should become accidentally divided. The necessity for the instantaneous application of the maximum brake-pressure throughout the train is so evident, that it is only necessary to recollect that at a speed which is not infrequently attained—60 miles per hour—a train passes over 88 feet in a second of time. In order to stop a train in the shortest possible distance, it is necessary, in the words of Captain Douglas Galton, C.B. :—1st, that the brake-blocks should act upon every wheel in the train; 2nd, that they should be applied with their full force in the least possible time; 3rd, that the pressure upon them should be regulated according to speed and other circumstances, so that the friction shall

nearly equal, but never exceed, the adhesion of the wheels upon the rails.

A consensus of opinion has not yet been attained, as to which is the best of the several brakes now at work on English railways. Unless different railway companies can arrive at a joint understanding to initiate and prosecute experiments for ascertaining the performances of railway brakes, the only means by which an independent inquiry could be made would consist of a Government Commission, appointed to lay down principles and to announce the facts.

Meantime, the following very full and illustrated account of the Westinghouse brake, one of the most prominent continuous brakes now in operation, will afford a large amount of useful information.

THE WESTINGHOUSE AUTOMATIC AND CONTINUOUS BRAKE.

The Westinghouse brake is continuous throughout the train. It is worked by compressed air, which is pumped into a large wrought-iron reservoir on the engine, generally fixed under the footplate. When the engine is attached to the train, the hose-couplings are united between consecutive vehicles, and all the cocks in the main pipe are open, except the cock at the rear of the train. The compressed air is turned into the main pipe, and the pressure is equal throughout the apparatus: the fittings, brake-pipe, triple-valve, small reservoir, and main reservoir; but the slide in the triple valve being lifted up over the port leading to the brake-cylinder, the air cannot enter *there*, and hence, of course, the brake-blocks are suspended away

from the wheels. When the driver perceives danger, or requires to stop—it may be as quickly as possible—he, by turning a cock on the engine footplate, lets some of the air out of the main pipe; this consequently and naturally causes the slide of the triple valve to drop, and this uncovers the port leading to the brake-cylinder, and at the same instant the slide, by moving down, covers the port leading from the brake-pipe to the small reservoir. It is a very simple and a most ingenious arrangement.

The compressed air in the reservoir rushes along with great rapidity and enters the cylinder, or brake-cylinder, and forces the two pistons apart. By this movement the blocks are brought into contact with the wheels. The air was confined in the little reservoir by a very small—one may say tiny—slide being held up by the air-pressure in the brake-pipe over the port. The driver lowers the slide at will, by reducing the air pressure; the valve, acting like a steam slide-valve, cuts off the power from the one port—to the reservoir—and admits it into the other port—to the brake-cylinder. The brake should only be used with its full force in cases of great danger. In ordinary working, the driver should put it on gently, and in such a way as will only reduce the pressure a few pounds—of from 4 lbs. to 8 lbs. per square inch. The brake, when fully set, reduces the pressure on the gauge, which is for the use of preventing extremes, about 25 lbs. No further escape of air is required, and the driver should shut the valve leading to the main reservoir.

For taking the brake off.—In releasing the brake, the driver moves the handle, by which he works the brake,

to the left, against the stop, and keeps it there for about five seconds, when he moves the handle back just far enough to close the communication between the main reservoir and the brake-pipe.

Uncoupling.—Before detaching the engine, the brake must be fully released on the whole train—that is, the main pipe and small reservoir must be charged with air. What for? To keep the slide of the triple valve up over the port leading to the cylinders, from which the brake-blocks are worked.

The brake-pipe, or main pipe, has a small tap at each end of each vehicle—tender, carriage, van, horse-box, carriage-truck, and everything else fitted with this brake. The taps must in all instances be closed before the hose coupling is disconnected. If this precaution be neglected when uncoupling, the brakes will be applied. It makes no difference whether the vehicles are separated by accident or by design. The great feature of the invention is the instant application of the brakes, when the triple-slide covers to the reservoir, and uncovers to the brake-cylinder. This always takes place unless the taps at the ends of each vehicle are closed. Even whilst the train is running it may thus be known whether they are open or not, and should the train part, the triple-slides instantly drop right and left everywhere in the train, and the brake is laid on.

Train separated by accident.—If the brakes be accidentally applied, they can be released by opening the small taps in the brake-cylinder, or pipes leading thereto; but these taps must be closed after the brake is released. In case of its breaking away when running, the engine has simply to be connected again, when the driver will charge the brake-pipe, which

lifts the triple-valve slide, and thus lets the air out of the cylinder into the atmosphere, as will be clearly illustrated farther on.

Casualties.—Should a pipe burst or get injured, the brake of any vehicle can be put out of operation without affecting the others, by closing the tap under the carriage between the brake-pipe and the triple-valve.

Description of Brake on Engine and Carriage.

The locomotive, Figs. 63, 64, is provided with a donkey-engine, A, and a double-acting air-pump, B, with suitable

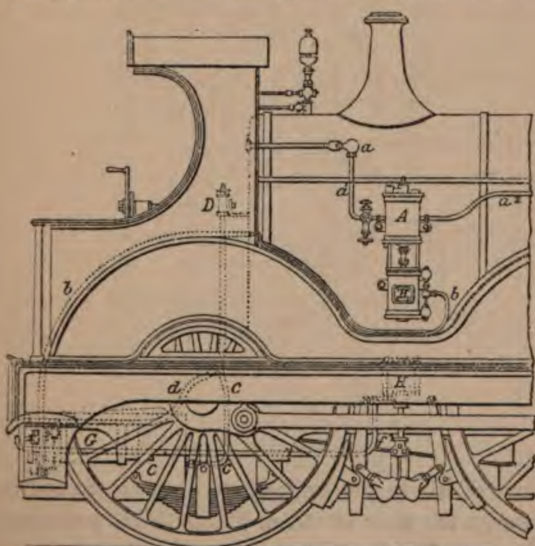


Fig. 63.—Engine: Side View.

valves, which are attached to the side of the boiler from which the engine is supplied with steam. Air is forced

into a wrought-iron cylindrical reservoir, C, attached to the lower face of the footplate. The pressure of air is considerable, namely, from 90 to 100 lbs. per square inch, and it is held in reserve for working the brakes on each vehicle when the train is about to stop at a station, or in case of danger. A gauge, d^2, shows the

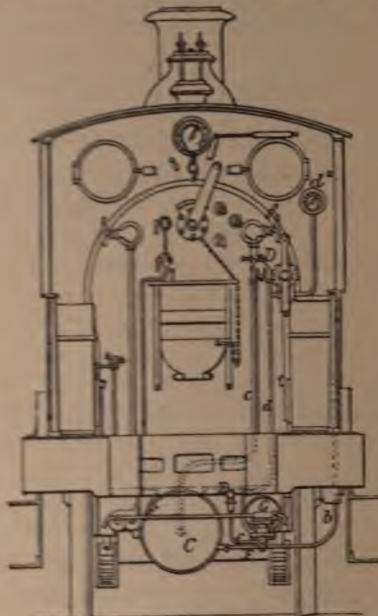


Fig. 64.—Engine: End View.

pressure of air in the brake-pipe. A steam regulator, a, governs the flow of steam to the donkey-engine, and regulates its speed, and consequently also the pressure of air in the main reservoir. The exhaust pipe, d^3, leads to the smoke-box. A driver's brake-valve, D, has one connection, c, to the main reservoir, and a

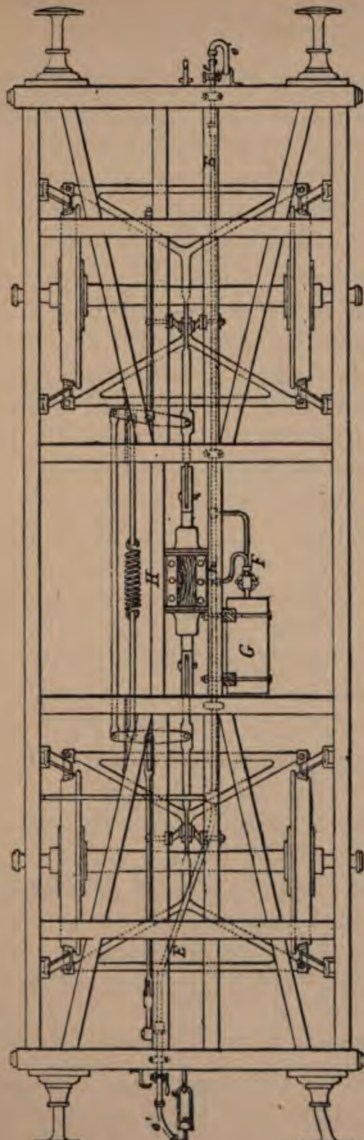


Fig. 65.—Carriage: Plan of Under-Frame.

second connection, *d*, to the brake-pipe E, running the entire length of the train. This brake-valve regulates the flow of air for supplying and releasing the brakes.

The driving-wheel brake-blocks are operated by one, and sometimes two, brake-cylinders, H H. From the brake-pipe E, branches *f* lead to each triple-valve F, in communication with a small reservoir, G; and the pipe f^1 leads to the brake-cylinders, H. Cocks, h^1, serve to close the branch-pipes *f* if required.

When air is admitted from the main reservoir on the engine into the brake-pipe E, Fig. 65, it passes into and through the triple-valves F, charging the reservoirs G with a pressure equal to that in the brake-pipe E. So long as the pressure in the brake-pipe is equal to or exceeds that in the small reservoirs, the passages from the triple-valves to the brake-cylinders H are closed. The pressure supports the slide of the triple-valve over the cylinder port, and this keeps, at the same time, a passage open from the cylinder to the atmosphere, and the brakes are off.

The stop-cock *h*, placed between the triple-valves and the brake-pipe, permits the brake of any one carriage, if necessary, to be put out of use, without affecting the brakes on the other carriages. The stop-cocks *e* are placed in the brake-pipe at the end of each vehicle, in order to close the brake-pipe at the rear of the train, and to prevent the escape of air when uncoupling.

The connections between carriages are made with flexible tubing e^1 of one inch in diameter.

Description of Air-Pump, Fig. 66.

Steam from the boiler enters between the two pistons of the main valve, 14. The upper piston being of

greater diameter than the lower, the tendency of the pressure is to raise the valve, unless it is held down by the greater pressure of the piston 20, working in the cylinder above it, which piston is held down by the pressure of steam admitted from the chamber A. This chamber is always in communication with the space between the two pistons of the main valve by means of a passage, *f*. As shown in the figure, steam is entering past the lower piston of the main valve and forcing the main piston, 6, upwards.

As the main piston completes its upward stroke, the plate 10 pushes up the rod 12, and with it the slide valve 13, closing the passage *a* from the chamber A to the cylinder 19, and at the same time opening the exhaust passage *b*, which relieves the pressure on the top of the piston 20.

By relieving the pressure on the piston 20, the steam in the main-valve chamber is permitted to raise the main valve and enter to the upper side of the main piston 6, and at the same time exhaust the steam on the lower side. On completing its downward stroke, the main piston again draws the rod 12 and valve 13 to the position shown, reversing the position of the main valve, and consequently the stroke of the main piston.

The air pump below is of the ordinary description.

The small cock on the left is for lubrication with refined petroleum.

Number and Names of Parts.

No. 1. Top head with valve and bush.
2. Steam-cylinder with main valve and bushes.
3. Centre-piece with stuffing-nuts.

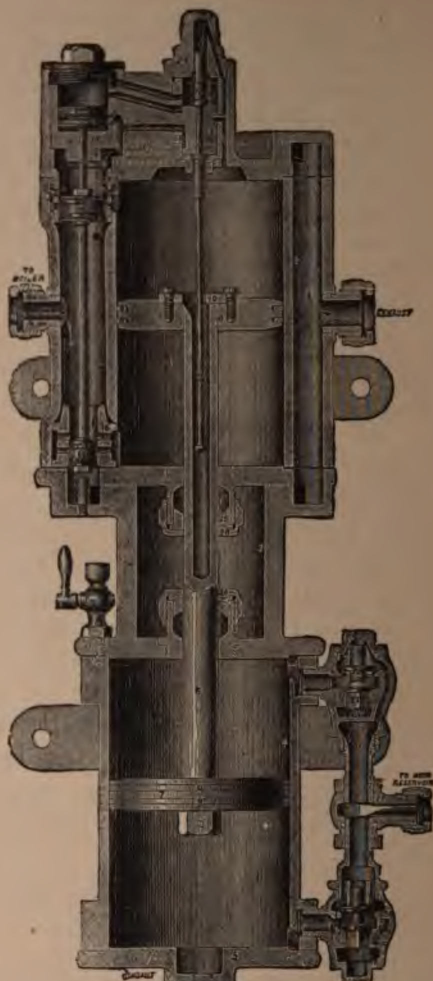


Fig. 66.—Air-pump.

4. Air-cylinder.
5. Air-cylinder head.
6. Main piston and rod.
7. Air-pump piston.
8. Steam-cylinder packing-rings.
9. Air-cylinder packing-rings.
10. Reversing valve-plate.
11. Reversing valve-plate screw.
12. Reversing valve-rod.
13. Reversing valve.
14. Main piston-valve.
15. Upper valve packing-ring.
16. Lower valve packing-ring.
17. Upper main valve-bush.
18. Lower main valve-bush.
19. Reversing piston-bush.
20. Reversing piston.
21. Reversing piston packing-rings.
22. Reversing piston chamber-cap.
23. Reversing valve-bush.
24. Reversing valve chamber-cap.
25. Piston packing-gland.
26. Piston packing-nut.
27. Upper air-valve case.
28. Lower air-valve case.
29. Valve case centre.
30. Upper valve case cap.
31. Lower valve case cap.
32. Air-discharge valve.
33. Air-receiving valve.

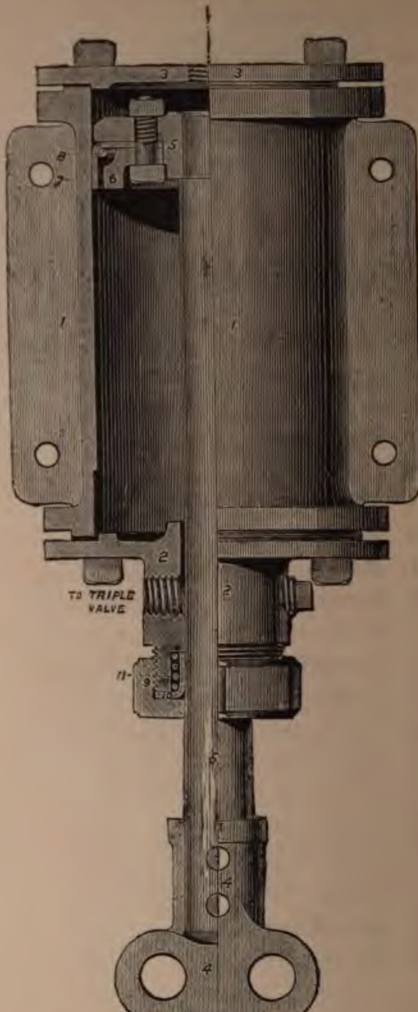


Fig. 67.—6-inch Driving-Wheel Brake Cylinder.

Description of Driving-Wheel Brake-Cylinder.

Cylinders of this form are used to apply the brake to the driving-wheels of engines, letter H, Fig. 63, where the piston cross-head is shown attached to the brake-blocks suspended between the driving and tracting wheel. Air is admitted below the piston 5, by the upward movement of which the brakes are applied.

Number and Names of Parts, Fig. 67.

No. 1. Cylinder body.
2. Lower cylinder-head.
3. Upper cylinder-head.
4. Piston cross-head.
5. Piston and rod.
6. Piston and follower.
7. Piston packing-leather.
8. Piston packing-expander.
9. Piston rod packing-nut.
10. Piston rod packing-leather.
11. Piston rod packing-ring.

Description of Driver's Brake-Valve, Fig. 68.

Air passes from the main reservoir into the chamber A, in which is the rotating valve 4, seated upwards by means of a spring 8. When the handle is in the proper position for filling the brake-pipe, the air passes through a port in the valve 4 into the chamber B and the brake-pipe, the discharge valve 3 being held to its seat by means of the spring 7. The spring 7 is held down by the handle 2, the rotary motion of which regulates the amount of pressure upon the spring by

the coarse screw. The valve 3 and rotating valve 4 turn with the handle 2. When the handle 2 is in its ordinary position during running, a passage of $\frac{1}{8}$ inch in diameter is open between the chamber C, in which is seated the small valve 6, and the chamber B, this opening being for the purpose of maintaining the pressure in the brake-pipe. The spring 9, which holds this valve to its seat, has a pressure of about fifteen

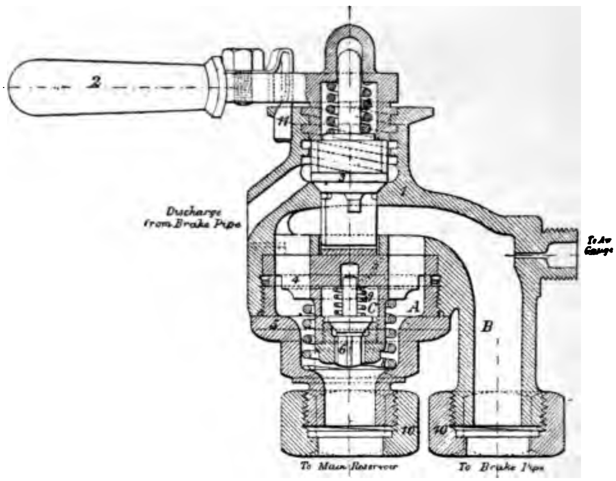


Fig. 68.—The Driver's Brake-Valve.

pounds, so that the pressure in the main reservoir must always exceed that in the brake-pipe by at least fifteen pounds. When the excess becomes greater than that amount, additional air passes into the brake-pipe until the spring is again able to close the valve 6.

To apply the brake the handle 2 is turned to the right. This relieves the pressure upon the spring 7 and

allows the discharge-valve 3 to be raised from its seat by the pressure of air in the chamber B, thus discharging the air from the brake-pipe and applying the brake. At the same time the valve 4 rotates with the handle, and this motion closes all communication between the chamber A and the chamber B.

If the handle 2 is turned to its farthest position to the right, the valve 3 gives a full opening to the discharge of air from the brake-pipe, and the brakes are applied immediately with full force, as in cases of emergency.

To release the brake, the handle 2 is turned to the farthest position to the left. This closes the discharge valve 3 by compressing the spring 7, and at the same time causes the valve 4 to turn to a position in which there is a free opening between the chamber A and the chamber B. This allows the brake-pipe to be recharged from the air in the main reservoir, and the brakes to be released. As soon as the brake-pipe is recharged the handle 2 is turned slightly to the right, or its normal position, closing the full opening between the chambers A and B, but leaving open the $\frac{1}{8}$-inch passage from the chamber C to the chamber B.

The object of allowing any excess of pressure created in the main reservoir to pass into the brake-pipe only through the $\frac{1}{8}$-inch passage is to provide for any gradual leakage, and at the same time to prevent the total escape of the air in the main reservoir in case of any sudden rupture of the pipe.

This valve is very simple in its operation, and admits of the most perfect graduation of the force with which the brakes are applied, irrespective of the number of vehicles in the train.

NUMBER AND NAMES OF PARTS, FIG. 68.

No. 1. Valve body.
2. Handle.
3. Discharge valve.
4. Centre valve.
5. Lower cap.
6. Receiving-valve.
7. Discharge-valve spring.
8. Centre-valve spring.
9. Receiving-valve spring.
10. Union nut.
11. Handle spring.

DESCRIPTION OF TRIPLE-VALVE, FIG. 69.

Air from the brake-pipe enters the lower part of the triple-valve, forcing the piston 5 into the position shown. The air then passes through the centre of the piston into the reservoir, and thus equal pressure is maintained in the latter, in the triple-valve and main brake-pipe, whilst the brakes are off.

The piston 5 carries with it a slide-valve 6, which, when in the position shown, establishes a communication between the cylinder and the atmosphere by the exhaust-port *b*. When the pressure in the main pipe is reduced by the driver or the guard operating his brake-valve, or by the separation of the train, or other accidental severance of the brake-pipe, the piston 5 is instantly forced down against the stem 7 by the higher pressure in the small reservoir, and thus prevents the return of any air to the main pipe. The piston 5 carries with it the slide-valve 6, which uncovers the passage *a*, allowing the air from the reservoir to flow

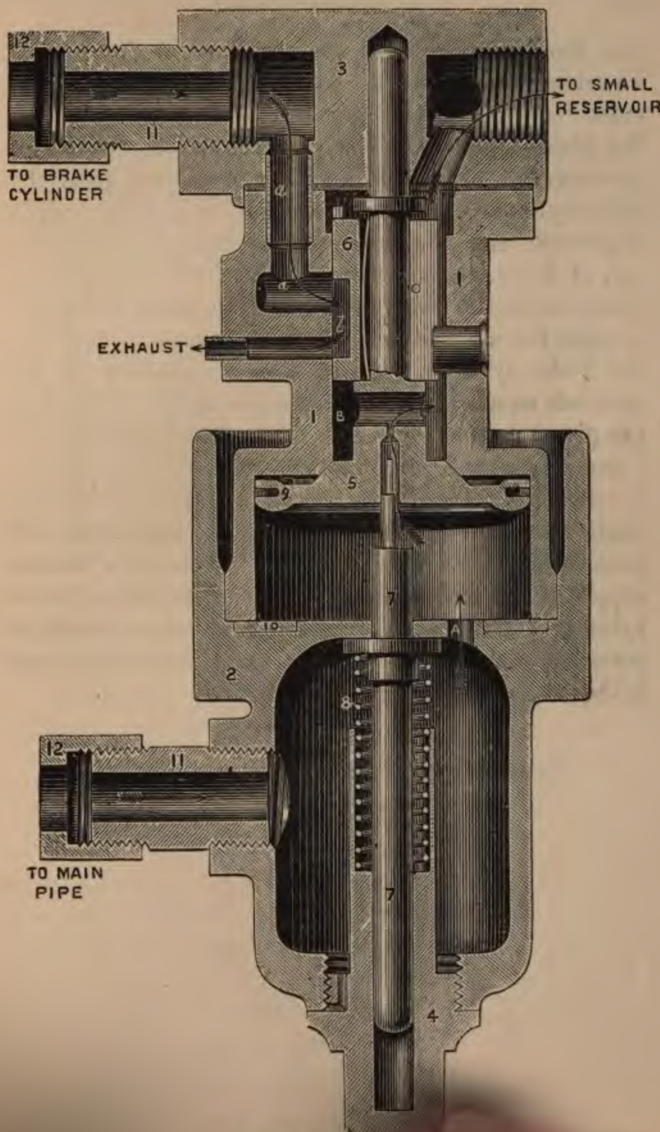


Fig. 69.—Triple V

into the brake-cylinder, and thus apply the brakes. To release the brakes, air is again admitted from the main reservoir to the main brake-pipe, which forces the piston again into the position shown, re-charges the reservoir, and permits the air to exhaust from the brake-cylinder. To apply the brakes lightly, only a slight reduction of pressure in the brake-pipe is made, say, of 5 lbs. per square inch. The piston 5 is forced down, causing the valve 6 to partially uncover the port *a*, when the air from the reservoir begins to flow into the brake cylinder. As soon as a reduction in the reservoir equals the reduction made in the brake-pipe, the piston 5 and slide-valve 6 are forced, by the stem 7 and its spring 8, just high enough to close the passage *a* without opening it to the exhaust-port. A further slight reduction of the pressure in the brake-pipe will produce the same operation, which permits a further supply of air to flow from the reservoir to the brake cylinder. The brakes are again released as before, by restoring the pressure in the main brake-pipe, and lifting the slide 6 of the triple-valve.

Number and Names of Parts, Fig. 69.

No. 1. Valve body.
2. Lower case.
3. Upper cap.
4. Lower cap.
5. Triple-valve piston.
6. Slide-valve.
7. Graduating stem.
8. Graduating spring.
9. Piston packing-ring.

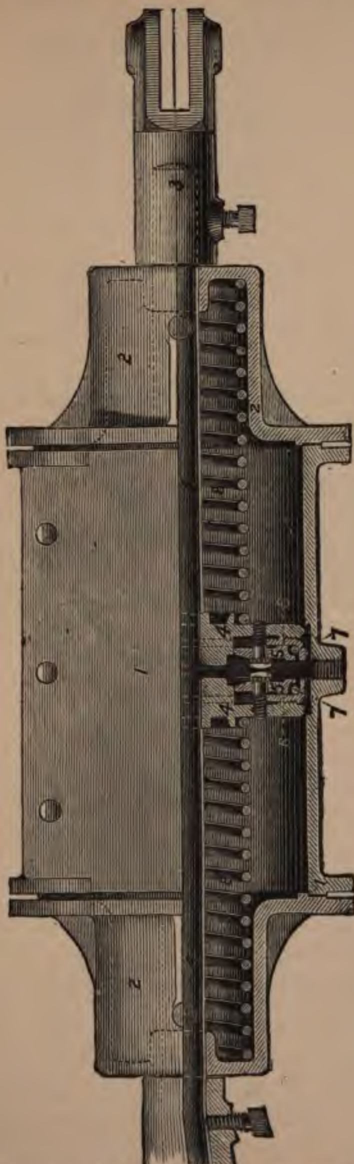


Fig. 70.—8-inch Double-Piston Brake-Cylinder.

10. Rubber packing-ring.
11. Half-inch nipple pipe.
12. Union nut.

Description of Double-Piston Brake-Cylinder.

When air is admitted to the cylinder, Fig. 70, the two pistons, 4, 4, are thrust outwards with equal force by air at about 80 lbs. per square inch, entering the cylinder at A.

When the air is allowed to exhaust into the atmosphere through the exhaust-port *b*, in the triple-valve, the springs 8 push back the pistons and release the brake-blocks from the wheels.

Number and Names of Parts, Fig. 70.

No. 1. Cylinder body.
2. Cylinder head.
3. Piston-rod sleeve.
4. Piston and rod.
5. Piston follower.
6. Piston packing-leather.
7. Piston packing-expander.
8. Piston release-spring.

Description of Couplings, Fig. 71.

The two couplings, 1, 1, are exactly alike, and an air-tight joint is formed by means of the rubber packing-rings 3, which rings face against each other when the couplings are united. The air-pressure in the coupling tends to force these rings towards one other, so that the joint becomes tighter with increase pressure. The tendency of the air-pressure in the

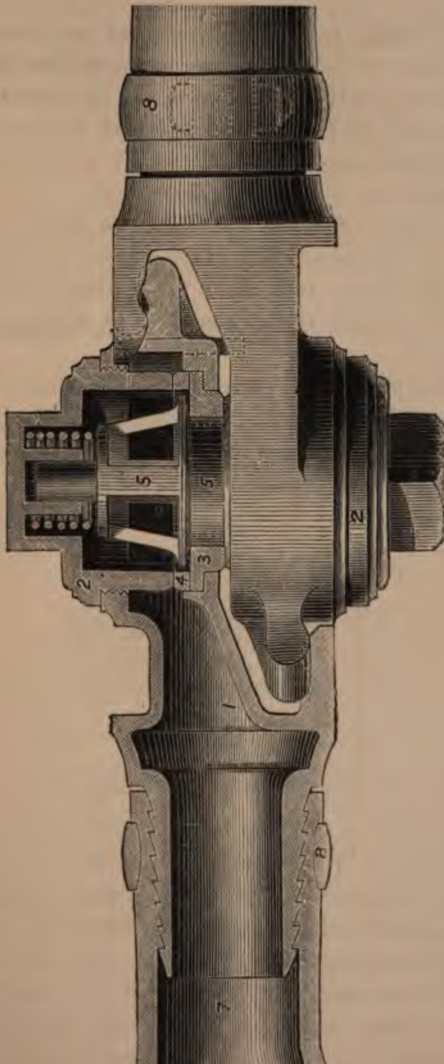


Fig. 71.—Couplings.

couplings is also to force them apart in a direction at a right angle to the line of the india-rubber hose-pipe 7, and consequently, the greater the pressure the more firmly are the couplings held together by the projecting piece of each coupling, which fits in a corresponding groove of the other coupling.

No damage is done if the couplings be drawn apart forcibly by the separation of the train, as the rubber rings 3 are forced into their respective couplings far enough to permit the projections to disengage from their grooves.

These couplings are united by placing them together, with one at right angles to the other, and then turning the projection of the one into the groove of the other.

Number and Names of Parts, Fig. 71.

No. 1. Coupling case.
2. Coupling cap.
3. Coupling packing-ring.
4. Packing-ring washer.
5. Packing-ring expander.
6. Coupling spring.
7. Coupling-hose.
8. Coupling-hose clamp.

Concluding Remarks.

It may be added, in conclusion, that the performance of the Westinghouse brake has been very fully and ably investigated by Captain Galton, in a long course of experiments conducted on the London, Brighton, and South Coast Railway, the results of which have been embodied by him in three papers

read before the Institution of Mechanical Engineers, in June and October, 1878, and in April, 1879. The reader who is desirous of informing himself of the working of that brake, cannot do better than study those elaborate and valuable papers. They will prove of much utility in forming public opinion, and in preparing a way for further legislation. It is not, of course, desirable that legislation should precede or forestall the evidence of facts; but, on the contrary, it is the bounden duty of legislators, so soon as the results of uniform experience provide the requisite unanimity of opinion and consequent authority, to give effect to educated public sentiment on the matter of train-safety.

In the meantime, the model engineer, model fireman, and model engine-boy, may well devote their attention to the working and performance of the brakes of the not-distant future, one of which has herein formed the subject for description.

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